For Reference

NOT TO BE TAKEN FROM THIS ROOM

Ex libris
universitatis
albertaensis

QUAECUMQUE VERA

The University of Alberta
Printing Department
Edmonton, Alberta

SPECIAL COLLECTIONS

UNIVERSITY OF ALBERTA LIBRARY

REQUEST FOR DUPLICATION

I wish a photocopy of the thesis by

MacIver, D.C. (author)

entitled Macroclimatic zonation in northern Alberta.

The copy is for the sole purpose of private scholarly or scientific study and research. I will not reproduce, sell or distribute the copy I request, and I will not copy any substantial part of it in my own work without permission of the copyright owner. I understand that the Library performs the service of copying at my request, and I assume all copyright responsibility for the item requested.

F. 236 September 1975

[illegible]

[illegible]

by

© [illegible]

A Thesis

Submitted to the Faculty of Graduate Studies

In Partial Fulfillment of the Requirements

for the Degree of Master of Science

Department of Geography

[illegible]

[illegible]

THE UNIVERSITY OF ALBERTA

MACROCLIMATIC ZONATION IN NORTHERN ALBERTA

by

© Donald C. MacIver

A Thesis

Submitted to the Faculty of Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree of Master of Science

Department of Geography

Edmonton, Alberta

Fall, 1970

Thesis
1970 F
176

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Macroclimatic Zonation in Northern Alberta", submitted by D. C. MacIver in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The primary objective of this research was to develop a climatic classification for a portion of northern Alberta at a scale detailed enough to be useful to vegetational management agencies. Previous classifications had either not achieved this level of detail, or had incorporated subjective biases into their zonations. Secondary objectives were (1) to evaluate the technique of thermo dew-point recording as applied to the macroclimatic zonation; and (2) to provide and analyze the characteristics of climate within the study area.

The data base consisted of temperature-precipitation records from first-order Department of Transport and Co-op stations; and from Alberta Forestry Lookout observing sites. Complete data for 1954 to 1968, for the months May to September, were available for very few of the 54 stations; such that, polynomial estimation techniques were employed to complete the data sets for each station. Arising from this, a climate description of the study area was computed.

A thermo dew-point recorder was employed in thrice daily routes in five separate areas within the study region. It was found that the climate stations were in many instances not representative of the climate in that area, but recorded only localized climatic conditions. In addition, physical conditions generalized for the study area were investigated, such as river valley, lake and topographical influences upon the climate. In conclusion, this instrument aided considerably in the placing of the macroclimatic boundaries.

Employing factor analysis, coupled with alogarithmic grouping methods, the stations in the study area clustered into thirteen

distinct climates. Detailed data descriptions of seventy-five input variables per station and associated seasonal variabilities are noted in the text. The results, therefore, satisfy the objectives of the study--namely, the delineation of climatically homogeneous areas in northern Alberta.

ACKNOWLEDGEMENTS

I am sincerely grateful to a number of people without whose help this thesis would not have been possible.

Collection of the required data and much of the analysis were carried out while I was employed by the Federal Forest Service. In particular, I would like to express my thanks to W. D. Holland for his continued faith and financial support, without which this project would not have been accomplished. To W. D. Holland and the Federal Forest Service I am sincerely indebted.

I wish to express my gratitude to my departmental supervisor, Professor R. W. Longley, for suggesting changes in the preliminary draft of this thesis. Also to Dr. K. D. Hage for his comments on the statistical analysis methods, I express thanks.

Moreover, I would like to thank Mrs. D. Keehn and Mrs. V. Wenger for a very commendable typing of the final draft. Appreciation is extended to Mr. Jack Chesterman for excellent reproduction of the maps and tables on very short notice. Similarly, I thank Miss D. Rose for her computer advice and suggestions throughout this thesis planning.

Finally, special thanks go to Miss G. Lamont, whose encouragement and support helped tremendously in the completion of this thesis.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

The climate of an area fundamentally governs the type and growth rates of the vegetative cover. Agencies such as the forest land capability sector of the Canada Land Inventory and forest management agencies require basic climatological information as an aid in forest land classification and management. In addition, research in a number of related disciplines requires climatological classification as a frame of reference for conducting research and using results for the benefit of management.

Existing classification techniques and results fail to provide adequate information on the desired scale for practical use in phytobiological research. The technique outlined in this manuscript attempts to provide a satisfactory solution. This, then, is the objective of the study; namely, an attempt to delineate areas having similar climatic regimes, based on statistical examination of those meteorological parameters normally measured at fixed weather stations. Contained within this broad goal are two secondary aims:

1) To provide and analyze the characteristics of climate within the study area.
2) To investigate the hypothesis that mobile thermo dew-point traverses are useful in locating climatic boundaries.

Method of Analysis

The progression of analysis (Fig. 1.1) is essentially composed of six steps from the original raw data input to the composition of final climatic maps.

The input parameters are supplied from four observation sources - three of these - first order, climatic, and forestry tower stations - in the form of pre-punched computer data cards purchased from the Department of Transport. The data base consisted of approximately 160,000 logical records, with access to approximately 200,000 additional input variable cards, such that little time was thereby involved in data collection for the above three mentioned station types. The fourth source of input variables - thermo-dew point recording - involved extensive field research within the study area, not only to provide additional raw data but to act as a testing mechanism on the representativeness of the above mentioned station data. More will be said on these topics in later chapters.

Step two of the analysis consists of data screening of the original input variables and data generation for missing days, weeks, months or years. Total completeness of each data set per station was required for further analysis, thus necessitating the statistical estimation, within preset error limits, of input parameters. Searching, comparing, eliminating faulty data and subsequent generating of complete data sets then provide the means for climatic analysis.

The third phase is the simple calculation of climatological long-term means per station for a number of meteorological variables - temperature, precipitation, frost, photoperiod, water-balance,

PROGRESSION OF ANALYSIS

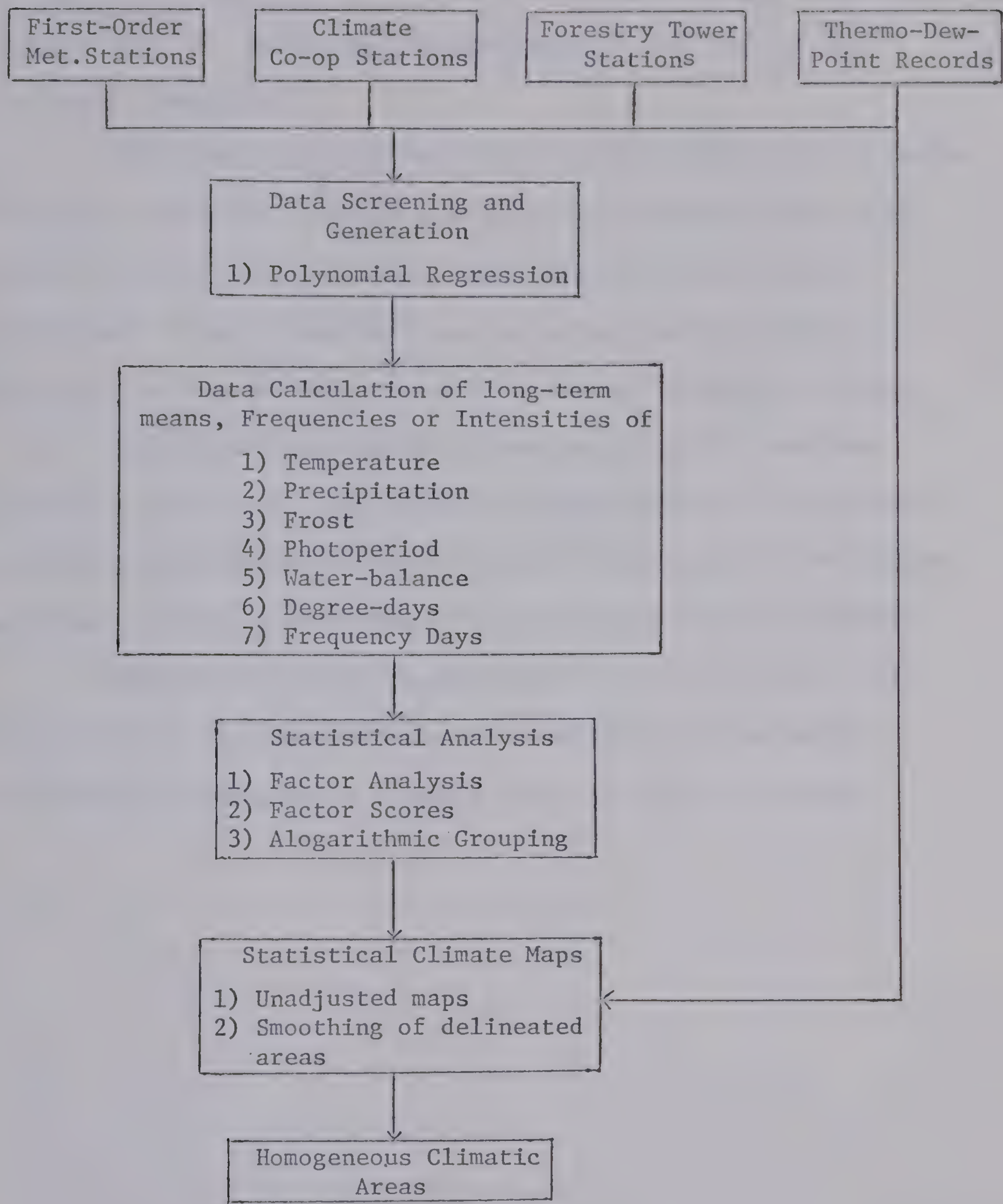


Figure 1.1

degree-days and day frequencies. Each of these accounted for an integral part of the 75 input variables to be utilized in the statistical analysis.

This, then, leads into step four in which application of factor analysis is employed to yield the associated principal factors per station. Using these as input, factor scores per station are calculated. These orthonormalized variables, scores, become input for the alogarithmic grouping of similar climatic stations.

Spatial portrayal of the climatically similar stations forms part one of the fifth step. By reapplication of the results found by thermo-dew-point recording and familiarity with the region, part two constitutes smoothing of these areally similar climates.

The sixth and final phase, once the areas are mapped, is able to fulfil the requirements of the objective of the study - delineation of homogeneous climatic areas in northern Alberta.[1]

[1] The study area chosen and respective station locations are found on the overlay in the envelope in the back cover of the thesis. This overlay becomes quite useful for determining the location of stations in association with various maps in future chapters.

Chapter 2

Climatic Classification

Derived from the early Greeks, the word climate denoted the azimuth of the sun in relationship to the earth's surface. After 600 B.C., temperature increases associated with southerly travel were noted by Hippocrates and Aristotle. This human awareness of the existence of climatic differences between various regions increased as early man explored new lands. An understanding of the interrelationship between weather, vegetation and soils which cause these spatial vagaries were at that time unknown. Comparison of simple qualitative estimates served as the first attempt at climatic classification. Descriptions of areas such as Arabia as hot and arid or Southern Europe as warm and moist, indicated the extent of early climatic perception.

Additional comparisons are illustrated in the Bible in which Egypt is recognized as a hot, dry, unfertile land, whereas Canaan is described as "a land of hills and valleys, and drinketh water of the rain of heaven". (Deuteronomy, Chap. 11). Abundant Biblical passages indicate both the dependence of these early agriculturists upon favourable temperature and precipitation regimes as well as the dependence of navigators upon the aspects of the wind-direction, frequency and intensity. These descriptive comparisons of regions served as viability indicators for early potential crop growth and management areas.

Moreover, some attempt was made, using crude wooden bowls

to collect rainfall, to analyze precipitation measurements for the purposes of agricultural forecasting. As early as 400 B.C. in India, the measurement of rain is recorded "In front of the storehouse, a bowl (Kunda) with its mouth as wide as an Arantani (18 inches) shall be set up as a rain gage" [Kautilya, 1915, p. 321]. Human heat sensitivity was, at that time, the only method of regional temperature differentiation.

Climatic Classification

Climatic stations quantitatively defined into spatially differing groups was first undertaken by Alexander Von Humboldt, usually referred to as the father of modern climatology. Subsequent classifiers, Griesbach (1872), De Candolle (1874), Sargent (1884), Drude (1890), and Merrian (1894) each postulated climatic grouping techniques. Although preliminary in view of modern techniques and data sources, each was perfectly accurate and meaningful at the time of presentation.

Koeppen

Refinement and representation of De Candolle's original five climatic-vegetational units by Koëppen, in 1918, opened the way for a host of classifiers and associated classification methods.

Based upon the interaction of temperature and precipitation amounts, Koeppen attempted to define vegetational similarities and differences on the basis of climatic variation. Boundaries are set for both temperature and precipitation means such that categorization of the stations is denoted by a series of three or more

alphabetic characters. The first two of these combine to indicate broad climatic types as shown in the following Table 2.1.

Table 2.1

	Main zones	Symbols	Subdivisions
A	Tropical rainy climates	Af	Tropical rain-forest
		Aw	Savanna
B	Dry climates	BS	Steppe
		BW	Desert
C	Temperate rainy climates	Cw	Warm, with dry winter
		Cf	Warm, moist all seasons
		Cs	Warm, with dry summer
D	Cold snow-forest climates	Df	Snow-forest, moist in all seasons
		Dw	Snow-forest, dry winter
E	Polar(snow) climates	ET	Tundra
		EF	Perpetual snow and ice

Based upon Koeppen's original classification, Alberta is composed of three types -- Dfc, Dfb or BSk. With direct application to the study area, Longley (1968) using the years 1931-1960, presented the patterns as shown in Figure 2.1. Only two climatic types are apparent - Dfc and Dfb. The letter D denotes one or more months at 50°F or over and one or more months under 26.6°F. Associated

CLIMATIC ZONES-KOEPPEN
1931-1960

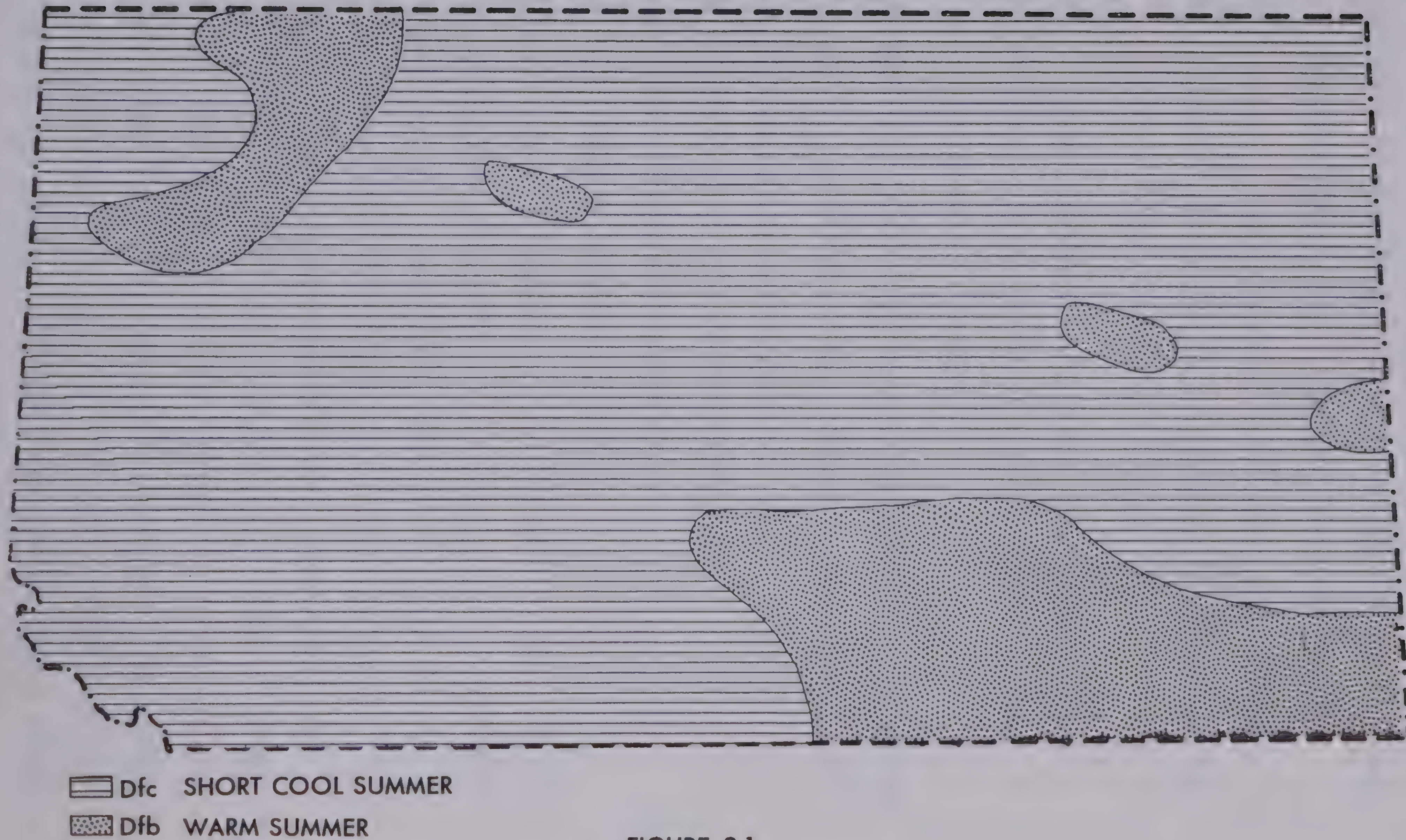


FIGURE 2.1

with this broad grouping are the possibilities of "f", "w" or "s". The letter "f" indicates adequate moisture throughout the year whereas the two remaining letters agree with the following criteria:

w - winter drought, summer rain. Rain of the rainiest month of summer at least ten times the amount of the rain of the driest month in winter.

s - summer drought, winter rain. Rain of the rainiest month in winter at least three times that of the driest month in summer.

The remaining set of letters, which complete the climatic definition terms, are defined according to the following temperature criteria:

a - warmest month above 71.6°F

b - four months or more above 50°F

c - one to three months above 50°F

d - coldest month below -36.4°F

Modifications to the above set of limits have ensued in an attempt to make the Koeppen model more representative in different geographical locations. With direct application to the Western Provinces of Canada, G. A. Rheumer in 1953 postulated three modifications to the original classification: namely, one, the redefinition of the year from the calendar year of Koeppen to the seasonal year ending in September, the reason being that winter is the dominant season in Canada; secondly, alteration of the boundary limit between the C and D climates to 32°F rather than Koëppen's original 26.6°F; and finally, instead of simply averaging a given

variable within a pre-set time period, the incorporation by Rheumer of the concept of the frequency of occurrence of that variable.

Spatial mapping of the like-climates resulted in the existence of seven climatic regimes, as shown in Figure 2.2, for the study area. Again, as with Koeppen, the arrangement of the letters denotes the importance of the varying facets of the climate. In all cases, the area is found within the Cold snow-forest climates with the major portion of the area associated with dry winter conditions (Dwf ..).

For example, the climatic type Dwfcb is characterized by a relatively dry to wet winter season and relatively cool to warm summers. However, broad regionalization of station data can lead to misleading results if the input parameters are not carefully chosen. For instance, the station Swan Dive (elev. 4174 feet) apparently has the same climate - Dwfbc - as the station Grande Prairie (elev. 2190 feet). Grande Prairie typifies the northern portion of agricultural land in Alberta whereas Swan Dive is characteristic of the non-arable forested land. These large differences in both land use and altitude at each station make the user skeptical that one climate overlays both regions. This is, however, not the fault of the classification system but, rather of the availability in 1953 of stations with long records available for use in classification.

In addition to Rheumer, Thomas (per. com.) altered the definition of the letters "f" and "w" such that if "less than 30 per cent of the annual precipitation fell during the months October to March, the station was then represented by 'w'" (Longley, 1970). The letter "f" still defined uniform precipitation throughout the

CLIMATIC ZONES-RHEUMER (after Koeppen)

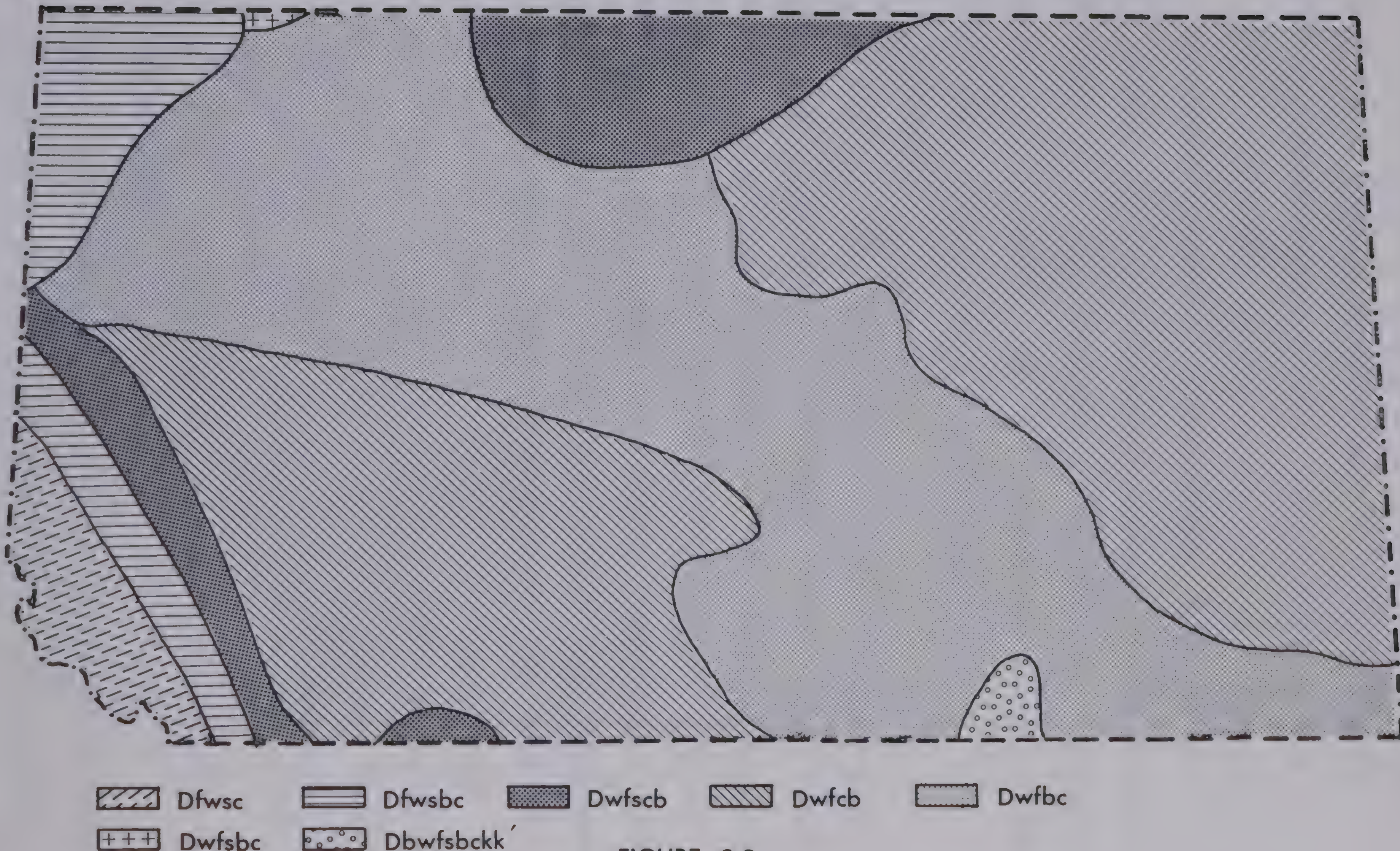


FIGURE 2.2

year. The resulting pattern, as shown in Figure 2.3, alters the previous climatic regions indicating that the southeast portion of the study area would experience winter drought conditions (Dw). The remaining portion with the exception of Wabasca, is classified as Df, using Koeppen notation. The redefinition of "w" on the basis of seasonal dryness or wetness, as opposed to simply Koeppen's ten times the driest month, provides a better indicator of precipitation amounts and variability. For all stations within the study area, ample moisture is available for the growing season - April to September.

As with most models, it is much easier to criticize than to suggest useful alternatives. The Koeppen classification technique has failed to satisfy many investigators - "The thermal criteria are unrelated to one another; criteria for dividing moist climates are rather diverse and most arbitrary; criteria for identification of the dry climates are far simpler than the task demands" (Carter and Mather, 1966, p. 316). In fact, it appears to many users of the model that attempts were made by Koeppen to fit the climatic classification to the observed vegetation units. But whatever inabilities within the model exist, it has been used throughout the world. Longley suggests that the simplicity of Koeppen's criteria is the major reason for its popularity (Longley, per com.).

Thornthwaite

Utilizing the same data sources and yet diametrically opposed in the approach to classification are the Koeppen and Thornthwaite methods. Unlike Koeppen, Thornthwaite placed the major emphasis

CLIMATIC ZONES-LONGLEY (after Koeppen)

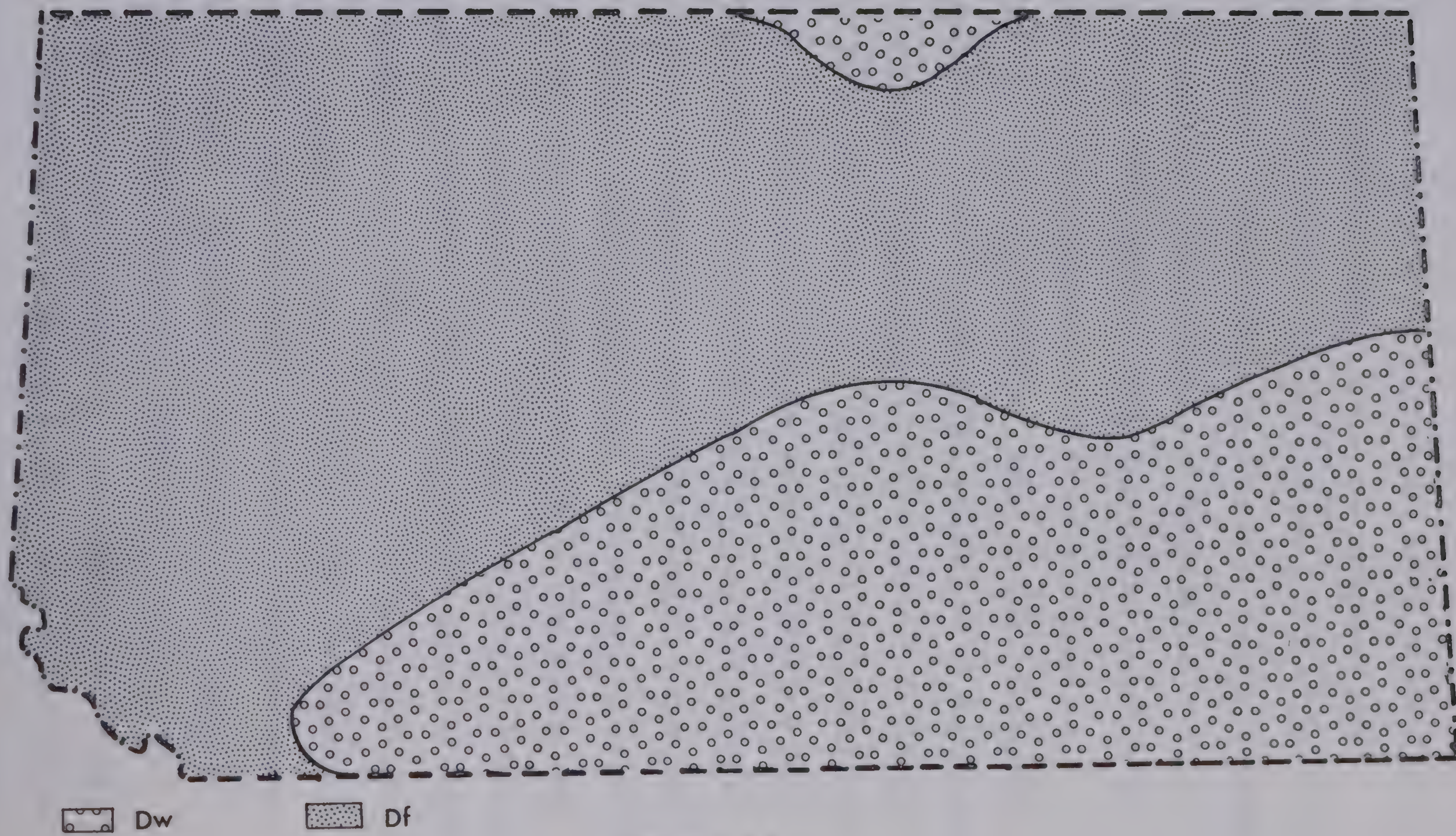


FIGURE 2.3

upon precipitation and moisture estimates rather than thermal variations. Improvements in the Thornthwaite model, as noted by his colleagues, Carter and Mather, follow the guidelines that " 1) he based the formulation of a moisture index on available evaporation records; 2) he used a simple moisture index to separate subtypes at regular numerical intervals of the index; and 3) he sought to construct climatic regions from regular intervals of his indices rather than from vegetation or soils criteria as Koeppen had done" (Carter and Mather, 1966, p. 317). Accomplishment of the above procedures involved the formulation of two indices called the precipitation effectiveness (P-E) ratio and the thermal efficiency (T-E) ratio. Subsequent comparisons of the indices with vegetational characteristics determined the class limits for each index. The one major failure of the system appears in the availability of adequate evaporation measurements necessary for the denominator of the P-E index calculations. Extrapolation of the existing evaporation values results in erroneous data, not present when actual reportings are employed. As a result, the patterns delineated by Thornthwaite, more accurate where adequate observations of needed data are possible, do not correspond to the patterns as outlined by Koeppen. Detailed criticisms of each method, by colleagues of Koeppen and Thornthwaite are quite prevalent in recent literature and research reviews. Criticism of Koeppen by Carter and Mather is illustrated: "although Koeppen's clasification continues to prosper in popular usage, its use lacks the support of a rational basis as a classification of climate or as an adequate development of the principles of classification which it introduced" (Carter

and Mather, 1966, p. 325).

Holderidge

Holderidge first postulated the model of climatically similar regions in 1947 but only in Spanish-language publications. Not until 1959 did articles appear in English, postulating a pyramidal model relating biotemperature, precipitation and potential evapotranspiration. Mean annual biotemperature is simply the mean of the positive daily temperatures in degrees Centigrade, divided by the number of days in the year. Multiplication of biotemperature by the empirical constant 58.93 yields the other variable - potential evapotranspiration (PE). Consequently, since PE varies directly as the biotemperature, the model essentially becomes a comparative analysis of precipitation and temperature variations at each station. Similar to the Thornthwaite approach, in attempting to delimit vegetational areas primarily on the basis of moisture availability, the Holderidge model received widest application in its area of formulation - the Tropics. Extrapolation outside the area of its development leads to misinterpretations in classification, a general criticism of most techniques.

Fairbairn

Climatic discrimination, as devised by W. A. Fairbairn (*Forestry*, 1967) was applied to the British Isles in 1967. The resulting phyto-biological zonations, as outlined in *Forestry*, combine three factors. Overlaying maps of the length of the growing season with average monthly temperatures reduced to sea

level with the map of rainfall amounts, Fairbairn arrived at thirty-two climatic subzones. Initially, a priori grouping of the input variables into pre-determined class limits simplified the task of amalgamating the three variable maps. Associated with each climatic region is a variety of meteorological parameters - mean range of temperature, mean minimum temperature, days of frost, sunshine, cloud, humidity and exposure.

This was the first major attempt to incorporate large numbers of input variables with subjective classification of each variable into groups before final clustering and interpretation.

Chapman and Brown

The aims and scope of this project, as noted by Chapman and Brown, are described as "A classification of Canadian lands ... for the purposes of the Agricultural and Rural Development Act. This account of climate of the settled parts of Canada is intended to aid in the land classification and it stresses field-crop relationships" (Chapman and Brown, 1966, p. 1).

In order to accomplish the above objective, overlaying of seven temperature zones with nine possible moisture classes created a possibility of sixty-three climatic types. The combination of these zones is illustrated in the climatic map for agriculture in Figure 2.4. The temperature zones 5, 6, and 7 are defined by Chapman and Brown as

5. 2,200 to 2,600 d.d. and 90 + f.f days
6. 1,800 to 2,200 d.d. and 75 to 90 f.f. days
7. less than 1,800 d.d. and less than 75 f.f. days

CLIMATIC ZONES-CHAPMAN AND BROWN

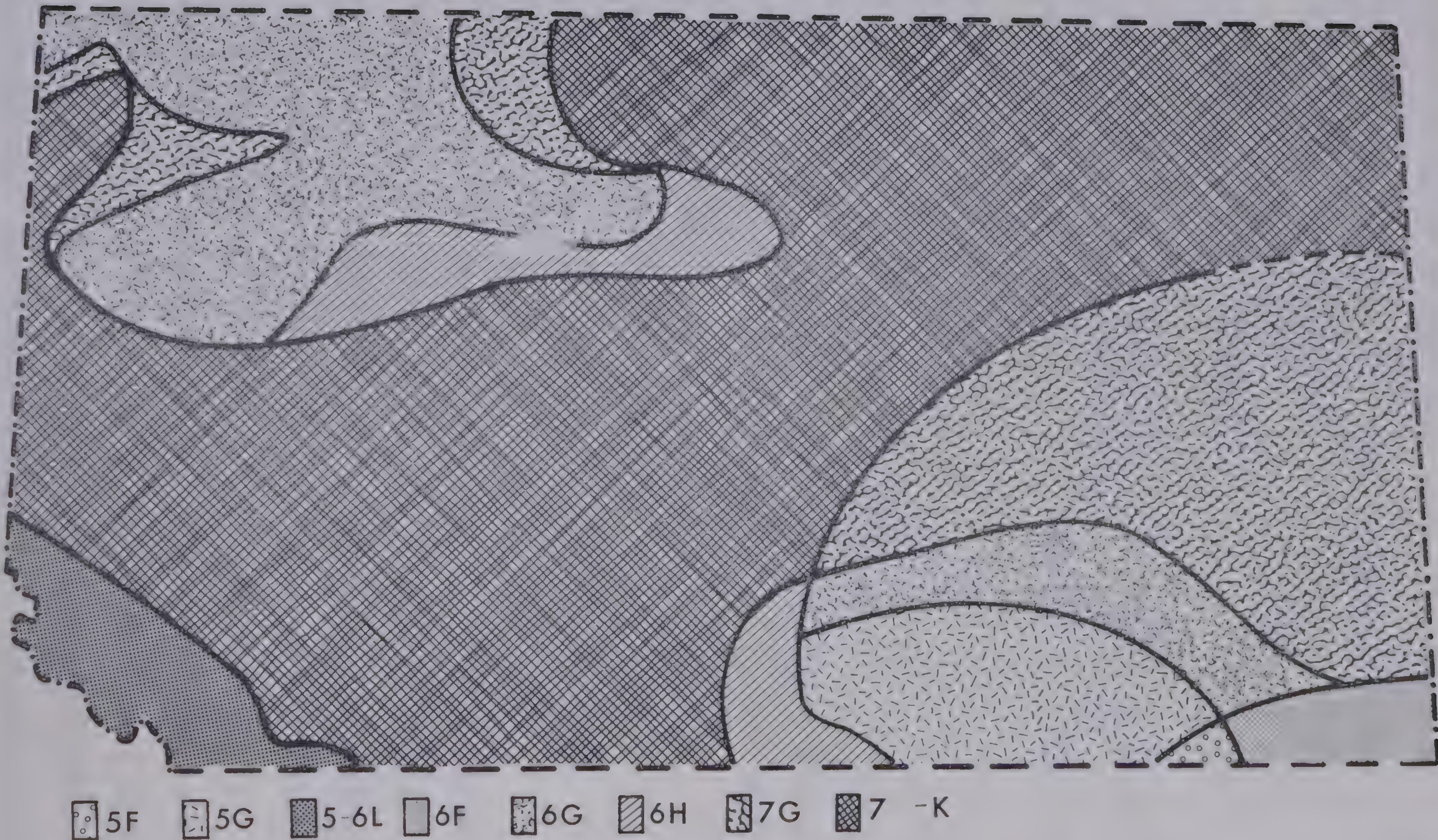


FIGURE 2.4

where d.d. is defined as degree-days above 42°F and f.f. are the frost-free days. Likewise, the respective moisture classes for the study area are illustrated in Table 2.2.

Table 2.2

Class	Water deficiency (inches)	May-Sept precipitation (inches)	
		Over 2600 d.d.	Under 2600 d.d.
F	7-5	10-12	9-11
G	5-3	12-13	10-13
H	3-1	13-15	12-15
K	1-0	15-16	14-18
L	0	-	16-20

d.d. - Degree-days above 42°F

Source: Chapman and Brown, 1966, p. 1.

Reference to the climatic map, Figure 2.4, indicates the existence of eight climatic regions. The forested portions of the study area are described by the climate 7H-K whereas the agricultural areas are subdivided into six climates. The mountain area is denoted by the climatic type 5-6L. In conclusion, the forested areas occupy the wetter cooler portions whereas the agricultural land is generally hotter and drier. Of particular note is the increased availability of moisture in response to eastward motion parallel with Lesser Slave Lake. The change from G to H with the same temperature class (6), indicates at least 2 inches more precipitation in the

Wagner-Slave Lake regions.

Newnham

Newnham (1968) as outlined in the publication Forest Science, objectively analyzed monthly temperature and precipitation averages. The previous methods described - Koëppen, Thornthwaite, Fairbairn - can be defined as representative of analog procedures - qualitative assessment of correlations and classification.

But because the data input is in the form of numerical values, it would seem only reasonable that the objective grouping techniques would eliminate the subjectively-defined anomalies and errors. Minimization of errors in classification by objectively weighting the input variables is therefore the main advantage of statistical as compared to subjective techniques.

Presenting a list of 19 variables - latitude, elevation, seasonal temperature extremes and frost - Newnham applies principal-component analysis to select only the statistically "most important" variables and to group these stations into climatic regimes. Applied to 70 stations in British Columbia, the station groupings compared quite well with the results obtained by the Chapman (after Koeppen) maps in 1952. Koëppen-defined stations were utilized as the base for comparison as presented at the British Columbia Natural Resource Conference (1952) by J. D. Chapman. Reclustering of some stations, wrongly classified by Chapman, becomes evident via the statistical mapping format. The subsequent correlations of the grouped stations with the vegetational patterns of British Columbia proved extremely accurate.

Consequently, principal-component analysis or simply statistical analysis is able to reduce large amounts of input data to meaningful and manageable variables as well as to provide a basis for objective classification of these climatically important variables.

Bowser

Practically orientated, Bowser sets out to provide an agro-climatic map which "delineates areas that have, on the long-term average, similar characteristics for cropping purposes" (Bowser, 1967). Correctly speaking, favourable areas of climate related to crop potential are delineated as shown in Figure 2.5. The numerals, ranging from 1 (best) to 5 (poorest) indicate the capability of that region for agriculture. Subsequent notations of heat (H) and aridity (A) outline the limiting growth factors. Broad generalization of areas with no associated numerical values limits the use of this approach for the agriculturist, forester or soil scientist. Various crop and forest species grow in response to different temperature and precipitation values. The classifying of Entrance, Kakwa and Edson stations in a similar climate to the Conklin and Heart Lake stations without adequate numerical notations is of little value to the phyto-biologist.

Regionalization of Climate

Associated with any grouping or clustering of point data into homogeneous regions is the problem of scale. The question then arises - are the regions delineated of the desired scale to fulfil

CLIMATIC ZONES-BOWSER

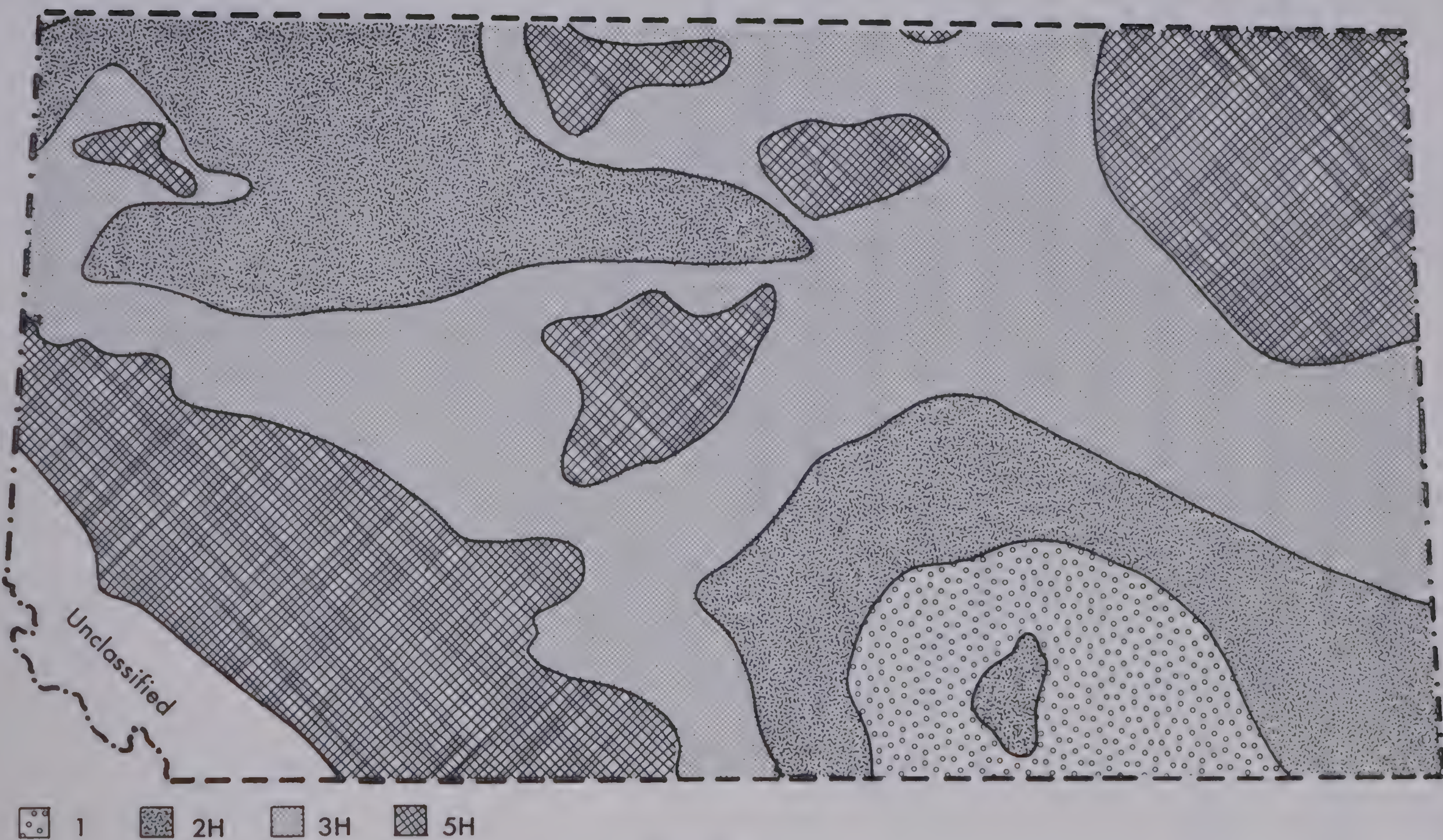


FIGURE 2.5

the objectives of the project? To be of practical use to the phyto-biologist, analysis of the region must be of a finer scale

than the Koëppen, Thornthwaite, Holderidge and Rheumer models. The patterns postulated by Bowser, if substantial definition and reclassification of the delineated areas were presented,appear to have the required detail at the macroclimatological level. Likewise, for the purposes of agriculture the Chapman and Brown delineated areas seemingly provide adequate detail. But better definitions of the forested areas are required by forest management agencies - the classification of the forested portion of the study area as one climatic type does not appear to be sufficient. It is hoped that the statistical climatic regions, outlined later in the thesis, will be of the desired scale, thereby providing a useful base for vegetational and soil research.

Chapter 3

Study Area Characteristics

Criteria for Selection of Study Area

Definition of the study area for this project was required to satisfy the following criteria:

1) That the climatic stations and the extent of the area chosen be of workable proportions such that the final processing and analysis of the data is not a complex and time-consuming task.
2) That the study area chosen be such that vehicular access can readily be obtained in order to ensure successful use of one of the basic data sources, namely mobile thermo - dew point recording.
3) That the area chosen must provide ample representation of a forest environment, because one of the specific applications of the project is a selection of forest site and management areas chosen with similar climatological regimes.
4) That the area exhibit vegetational and topographical variations to supply climatic variability, thereby ensuring more than one climatic zone.

In order to satisfy the above criteria, a band across the province from 53° 10' to 56° 10'N was selected (Fig. 3.1). The Rocky Mountain Forest Region located south of the study area was excluded on the basis of incomplete and non-representativeness of the meteorological reporting stations. Moreover, the lack of required data and the extreme variability among the mountain reporting stations resulted in its exclusion. The region north of latitude 56° 10'N was eliminated

LOCATION OF STUDY AREA IN ALBERTA

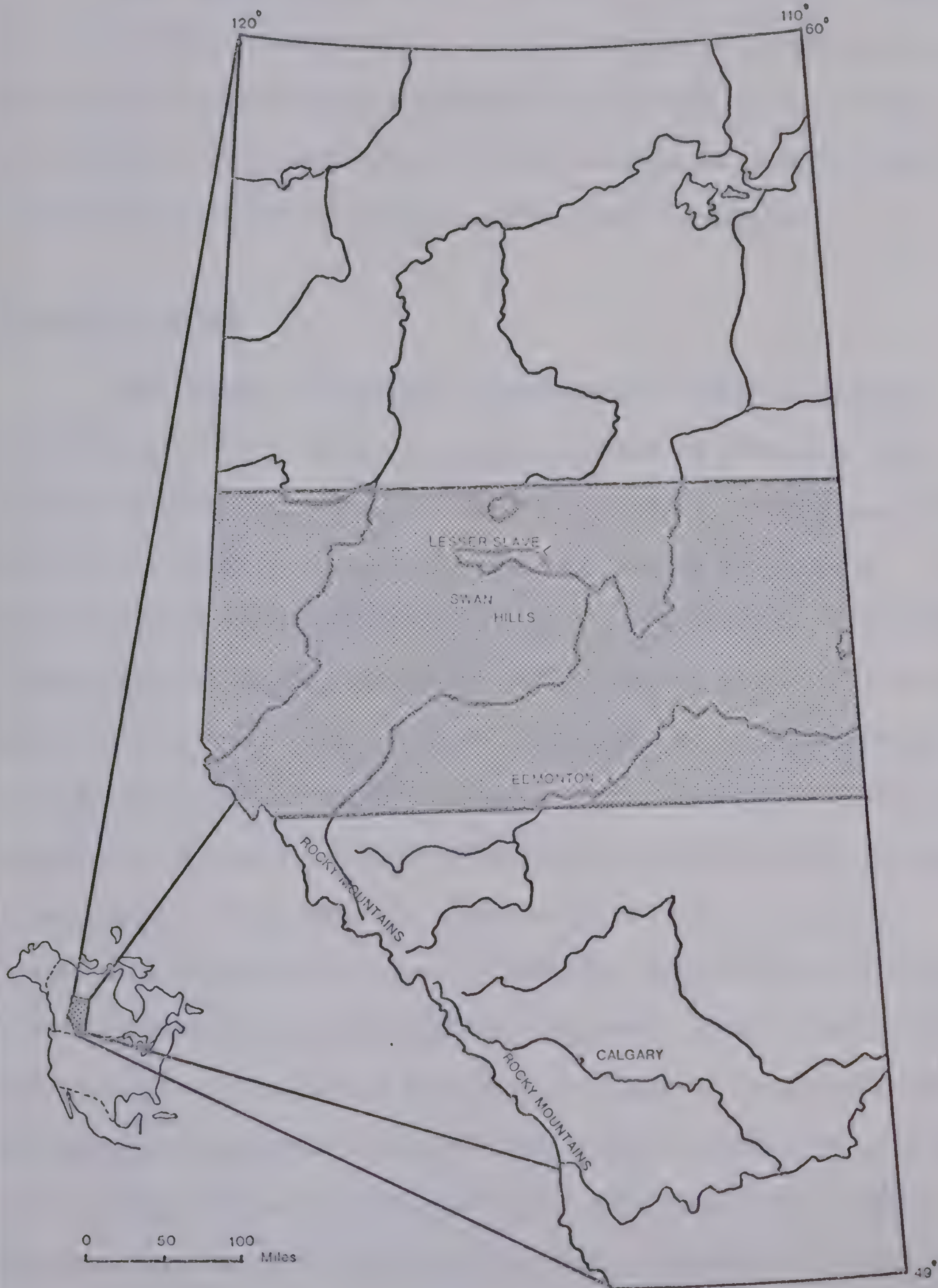


FIGURE 3.1

mainly because of the lack of an adequate density of roads for mobile examination of temperature variations.

The remaining area of the province, the study area, exhibited all the needed characteristics: a relatively dense network of reporting stations of manageable proportions; accessibility for mobile recording; adequate portrayal of forest environments; and finally, abundant topographical, vegetational and soil variations.

Climatic Stations

Department of Transport Meteorological stations, Climate stations and Alberta Forestry stations combine to provide a dense network of observing sites. Of the 131 reporting, 54 stations were chosen, providing as close to 15 years of records as possible. Of these selected stations (Table 3.1), only eight stations - Fairview, Grande Prairie, Wagner, Whitecourt, Edson, Lac la Biche, Cold Lake, and Vermilion - are operated by the Department of Transport Meteorological Branch. Each of these stations reports occurrence of precipitation, temperature extremes, synoptic conditions and hourly winds. Synoptic reportings per hour, with the exception of Fairview, consist of cloud, wind direction and speed, visibility, present and past weather, sea-level pressure, air temperature, dew point, pressure and pressure tendency, precipitation and snow amounts, depth of snow, and maximum and minimum temperature. The remaining stations within the area of study normally report only precipitation and temperature extremes. Consequently, the input variables for later statistical analysis are geographic location and temperature, precipitation and derived

Table 3.1

TYPE OF CLIMATIC OBSERVATIONS TO 1968

STATION	LATITUDE (°N) DEG.	MIN.	LONGITUDE (°W) DEG.	MIN.	ELEVATION FEET	PR.	TEMP.	SYN.	HOUR. WINDS	SUN.	YEARS OF REPORTING TEMP. & PREC.
1. Athabasca	54	43	113	17	1700	x	x				31
2. Athabasca 2	54	49	113	32	1900	x	x				11
3. Bald Mountain Lookout	54	49	118	55	3080	x	x				4
4. Beaverlodge CDA	55	11	119	22	2500	x	x		x	x	56
5. Calmar	53	15	113	50	2200	x	x				54
6. Campsie	54	08	114	41	2200	x	x				57
7. Carrot Creek Lookout	53	27	115	52	3425	x	x				18
8. Cold Lake A	54	25	110	17	1784	x	x	x	x		17
9. Conklin Lookout	55	37	111	11	2200	x	x				5
10. Deer Mountain Lo.	54	55	115	09	3680	x	x				7
11. Doucette Lo.	55	49	114	18	2000	x	x				5
12. Economy Lo.	54	47	118	14	2625	x	x				7
13. Edson	53	35	116	25	3027	x	x	x	x	x	55
14. Elk Point	53	53	110	54	1920	x	x				58

STATION	LATITUDE (°N) DEG.	MIN.	LONGITUDE (°W) DEG.	MIN.	ELEVATION FEET	PR.	TEMP.	SYN.	HOUR. WINDS	SUN.	YEARS OF REPORTING TEMP. & PREC.
15. Entrance	53	22	117	42	3300	x	x				52
16. Fairview	56	04	118	23	2160	x	x		x	x	38
17. Falher	55	45	117	12	1910	x	x				21
18. Fort Saskatchewan	53	43	113	10	2050	x	x				11
19. Goose Mountain	54	45	116	04	4600	x	x				5
20. Grande Prairie A	55	11	118	53	2190	x	x	x	x		25
21. Heart Lake Lookout	55	00	111	20	2910	x	x				5
22. High Prairie	55	26	116	30	1968	x	x				42
23. Hinton	53	24	117	33	3325	x	x				13
24. House Mountain Lookout	55	02	115	37	3780	x	x				6
25. Iron River	54	25	111	00	1900	x	x				44
26. Kakwa Lookout	54	26	118	58	3980	x	x				4
27. Kinuso	55	20	115	26	1928	x	x				4
28. Lac la Biche A	54	46	112	01	1835	x	x	x	x		11
29. Marten Mountain Lookout	55	30	114	42	2950	x	x				6
30. Meanook	54	37	113	21	2250	x	x				52
31. Newbrook	54	20	112	57	2200	x	x				14

STATION	LATITUDE (°N)		LONGITUDE (°W)		ELEVATION	PR.	TEMP.	SYN.	HOUR. WINDS	SUN.	YEARS OF REPORTING TEMP. & PREC.
	DEG.	MIN.	DEG.	MIN.	FEET						
32. Pelican Mountain Lookout	55	37	113	34	3000	x	x				10
33. Pimple Lookout	54	30	115	28	3619	x	x				7
34. Puskwaskau Lookout	55	13	117	30	3190	x	x				4
35. Ranfurly	53	27	111	39	2250	x	x				64
36. Rochester	54	22	113	21	2050	x	x				13
37. Round Hill Lookout	55	18	111	59	2460	x	x				5
38. Rycroft	55	46	118	38	1983	x	x				38
39. Salt Prairie Lookout	55	40	115	50	2350	x	x				5
40. Simonette Lookout	54	14	118	25	4180	x	x				5
41. Sion	53	54	114	06	2300	x	x				58
42. Slave Lake	55	17	114	46	1920	x	x				41
43. Snuff Mountain Lookout	54	41	117	32	3180	x	x				5
44. Swan Dive Lookout	54	44	115	13	4174	x	x				6
45. Sweathouse Lookout	54	55	116	45	2800	x	x				5
46. Thorsby	53	14	114	02	2450	x	x				33

STATION	LATITUDE (°N) DEG.	LATITUDE (°N) MIN.	LONGITUDE (°W) DEG.	LONGITUDE (°W) MIN.	ELEVATION FEET	PR.	TEMP.	SYN.	HOUR. WINDS	SUN.	YEARS OF REPORTING TEMP. & PREC.
47. Vegreville CDA	53	29	112	02	2086	x	x				13
48. Vermilion A	53	21	110	50	2037	x	x	x	x		24
49. Wabasca RS	55	58	113	50	1720	x	x				54
50. Wagner	55	21	114	59	1915	x	x	x	x	x	26
51. Whitecourt	54	08	115	40	2430	x	x	x	x		24
52. Whitecourt Lookout	54	02	115	43	3940	x	x				7
53. White Mountain Lookout	55	42	119	14	3585	x	x				5
54. Yellowhead Lookout	53	14	117	09	4800	x	x				5

PR. - PRECIPITATION   TEMP. - TEMPERATURE   SYN. - SYNOPTIC   SUN. - SUNSHINE

Source: Potter (1965)

functions of these.

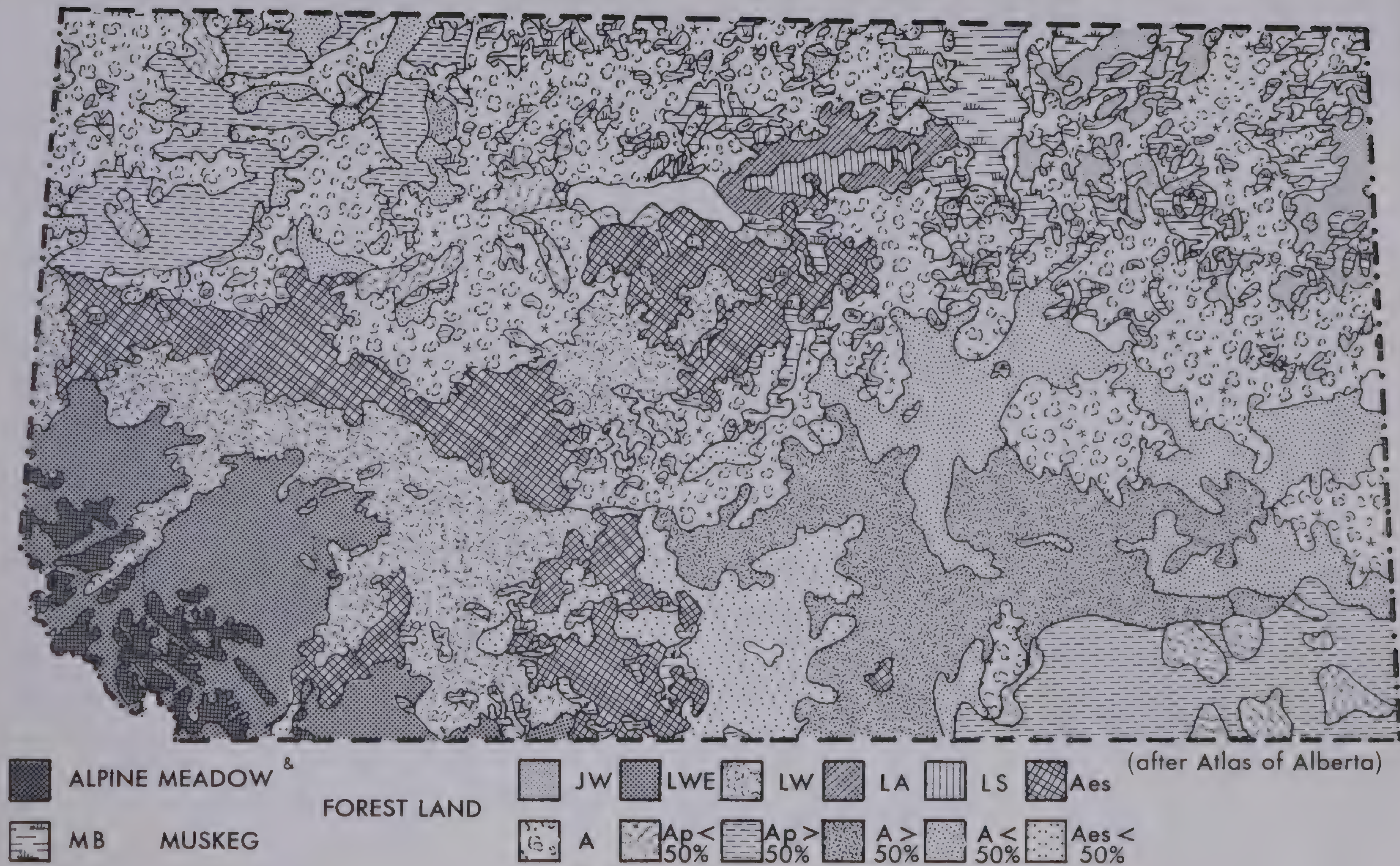
Vegetation

Broad regions or areas of non-forested land (Fig. 3.2) where more than 50% of the land is cultivated are found around such stations as Campsie, Edmonton, Thorsby, Calmar, Fort Saskatchewan. A lesser degree of cultivation (less than 50% cultivated) is dominant in numerous small "patches" in the region surrounding Grande Prairie. An additional area including Cold Lake, Iron River, Lac la Biche and Athabasca completes the extent of cultivation within the study area. The area remaining is characterized by forested regimes.

Aspen Poplar Parkland is found in conjunction with the areas where cultivation is less than 50 per cent. In general, the forested areas can be considered as containing primarily Aspen Poplar forest growth denoted by A in Figure 3.2. Found in the immediate vicinity of the Rocky Mountains are Lodgepole Pine, White Spruce and Engelmann Spruce. Between this latter mentioned species and the Aspen Poplar forest regions are two bands composed of Lodgepole Pine-White Spruce and Aspen ecotone to Spruce.

There is a progression from Aspen in the southeast to Aspen Poplar to Aspen Ecotone to Spruce to Lodgepole Pine-White Spruce to the combination of Pine and Spruce in the Mountains within the study area. Figure 3.2 gives the actual vegetational type for each station, as provided by the Atlas of Alberta.

VEGETATION OF THE STUDY AREA



& SEE APPENDIX B

FIGURE 3.2

Topography

Topographically, extreme variation is found within the study area, ranging from 1000 to 8000 feet (Fig. 3.3).

Considering only the spot elevations of all reporting station, the mean elevation was found to be 2618 feet above sea level with a standard deviation of 819 feet. Of the stations selected for study, Yellowhead Lookout indicates the highest at 4800 feet and Athabasca the lowest at 1700 feet above sea level.

These spot elevations, however, do not characterize the general topographic variability within the region. Progressing from the southwest corner of the study area to the northeast, elevation changes from approximately 8000 feet to approximately 1000 feet above sea level. This is in general a decrease in elevation with the exception of two large geomorphic anomalies. Rising out of a surrounding plain lying between 2000 and 3000 feet above sea level, Swan Hills reaches a height of 4000 feet. These Hills are represented by such stations as House, Goose, Deer, Pimple Mountain and Swan Dive. Substantial elevational increases of more than 2500 feet are noted between such stations as Swan Dive (4174 ft.) and Athabasca (1700 ft.). The second high area lies east of the Athabasca River and includes the stations Round Hill and Heart Lake. A longitudinal depression of 1000 - 2000 feet below the surrounding plain stretches from Rycroft on the west to encompass Slave Lake on the east. Otherwise with the exception of point height increases, e.g. Marten Mountain, the area has a general slope to the northeast.

Trend surface analysis interpolates objectively between

TOPOGRAPHY OF THE STUDY AREA

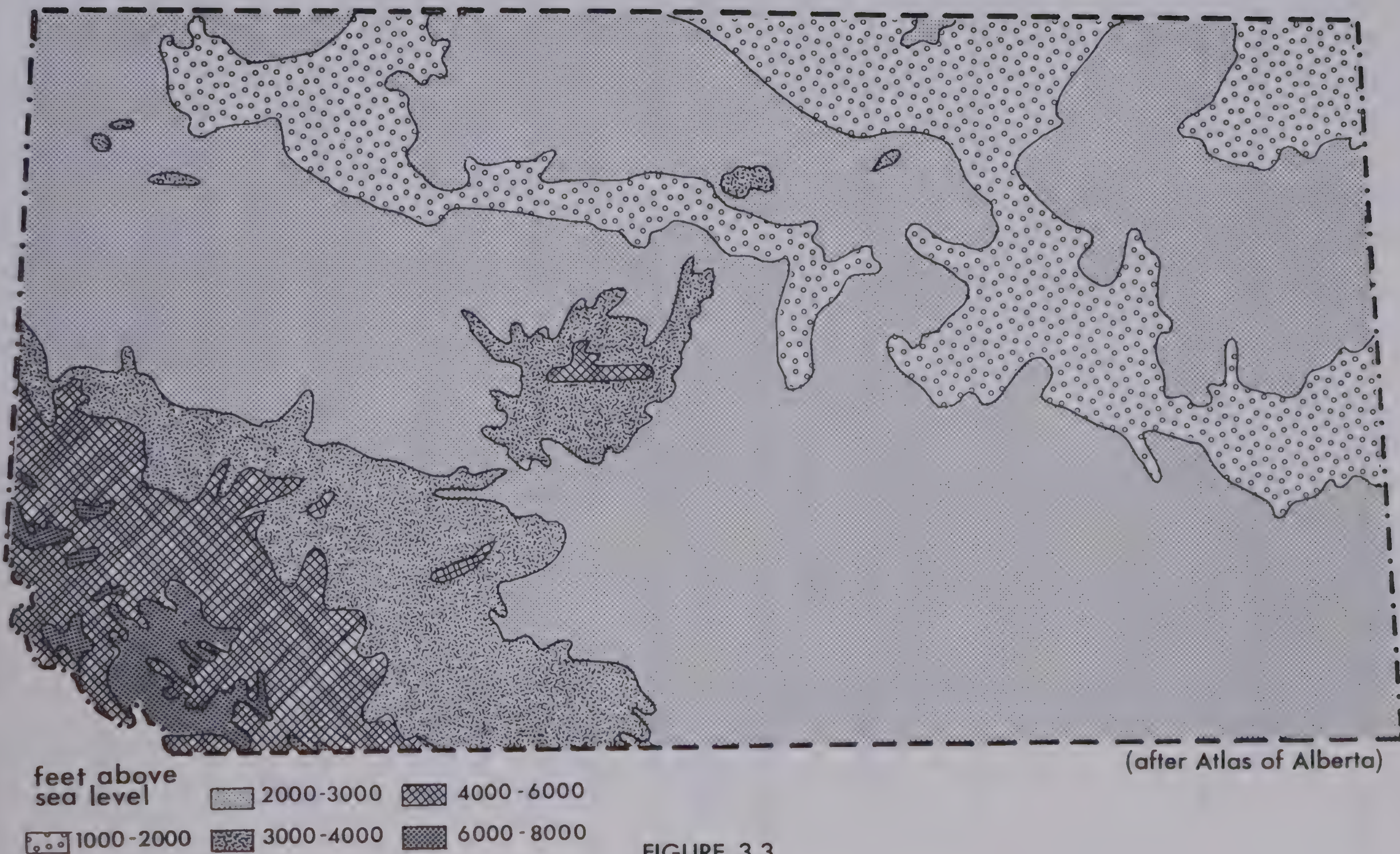


FIGURE 3.3

discontinuous (point) observations such that possible responses in areas not recorded can be estimated. Utilizing all the station heights and locations in the study area as input, a general cubic trend is applied through the use of multi-polynomial regression equations. Again, a predominant northeast slope from the southwest of the study area is indicated.

Soils

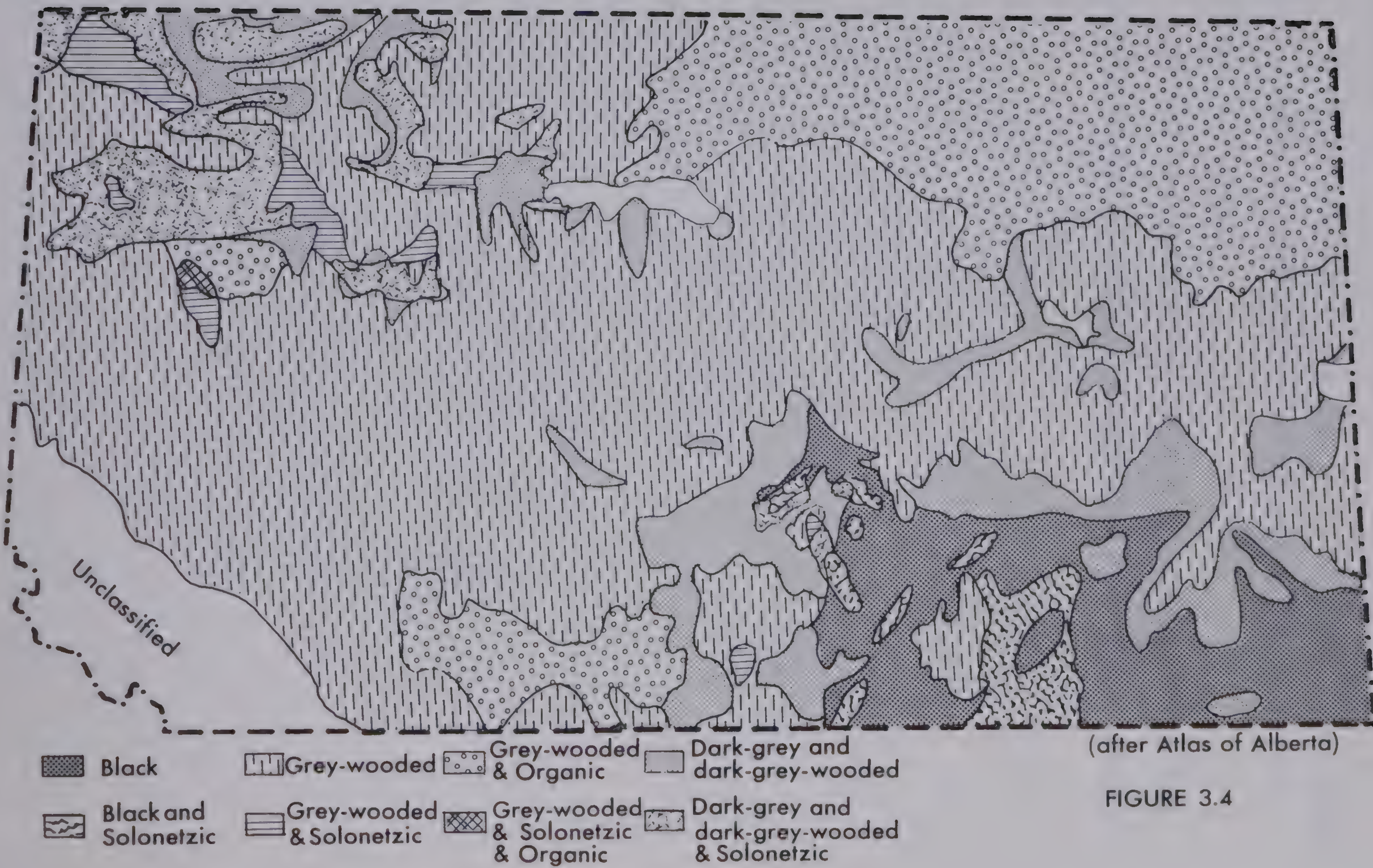
For the most part, the soils of the study area (Fig. 3.4) are classified as grey-wooded, supporting mixed farming specializing in hays and coarse grains. Within this soil grouping is found the majority of forested land classified as Aspen, Poplar or Pine.

To the north in the area surrounding Grande Prairie, the dark grey and dark grey wooded soils predominate. Associated with these areas are dominantly solenetzic soil deposits. Solenetzic is the accumulation of clay-pan soils usually requiring fertilization and crop rotation are required. Again as in the grey-wooded, mixed farming dominates the agricultural land use. A similar area is found in association with stations such as Campsie, Sion, Newbrook, Ranfurly, and Elk Point.

Found in the areas bounding the grey-wooded soil group, the black zone is located in the southeastern section of the study area. Described as arable land, this soil is found in association with Aspen-Poplar Parkland, uniform topography and more than 50% cultivated. Again an apparent accumulation of solenetzic soils is associated with this soil.

The region in close proximity to the Rocky Mountain has as yet

SOILS OF THE STUDY AREA



(after Atlas of Alberta)

FIGURE 3.4

to be classified.

Of particular note is the area to the northeast, e.g. Conklin, where some commercial exploitation of the organic deposits, peat, within the soil occurs.

With the exception of the black zone and dark grey to dark grey-wooded regions, the land is generally of a non-arable quality.

Chapter 4

Primary Data Input

In order to develop meaningful climatic regimes, long-term normals for the selected stations are needed. Because of the lack of these published normals for forestry tower sites, pre-punched computer card and subsequent analysis were able to supply the required averages for the years 1954-1968, inclusive. The primary data source consisting of point station observations in the form of number four daily climatological cards was purchased and supplied by the Federal Forest Service. Because the supplied data were discontinuous with regard to days, months and years, it was necessary to employ statistical estimation techniques to create complete reports for each day of the period May 1st to September 30th, between 1954 and 1968 inclusive.

This following chapter then, describes the data available on the number four daily climatological cards, the processing of these data, and the data generation methods used to complete the data base.

Number Four Daily Climatological Computer Cards

Pre-punched computer cards are able to supply the variety of climatic variables observed at meteorological stations across Canada. Figure 4.1 serves as a sample of the supplied cards, providing the complete set of observations at first-order meteorological stations, not typical of the majority of reporting stations in the

SAMPLE OF NUMBER 4 DAILY CLIMATOLOGICAL COMPUTER CARDS

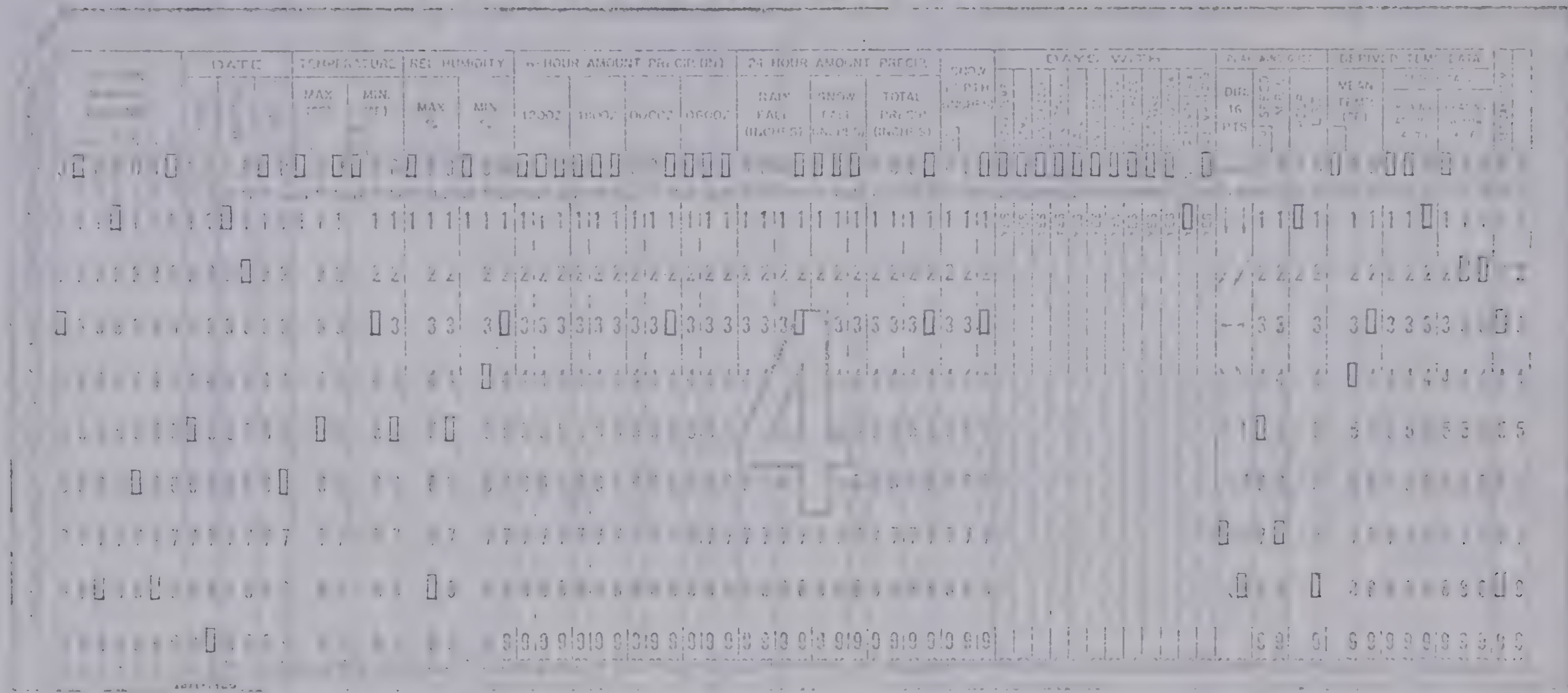


FIGURE 4.1

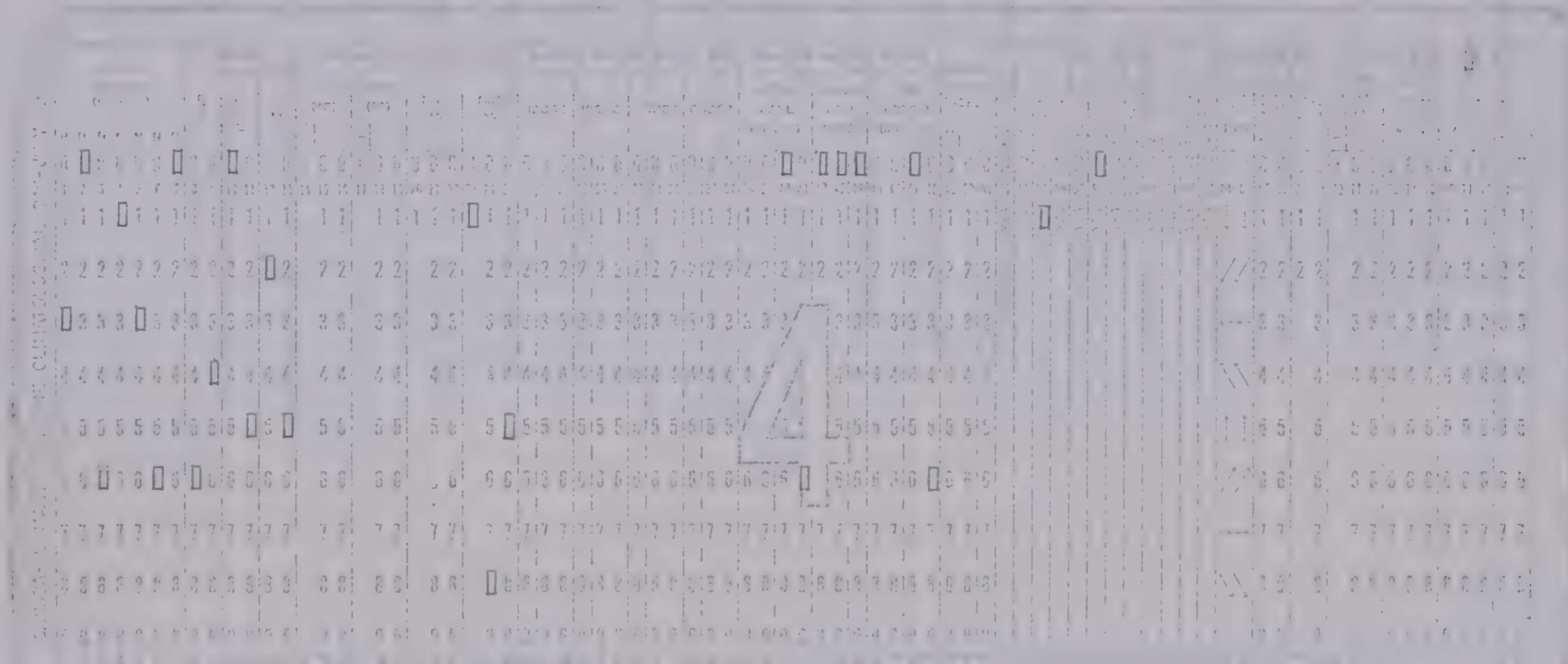


FIGURE 4.2

area of study. Figure 4.2 provides the comparative representative card data for the climate and forestry tower stations.

Functionally, for the majority of stations, the number four cards can be expected to report only daily maximum, minimum and mean temperatures, precipitation totals and growing-degree days.

First-order meteorological stations reporting synoptic conditions also supply six-hourly precipitation totals, relative humidity, and wind direction and velocity. Owing to the scarcity of these stations within the study area (8 out of 54), reduction of these data to temperature-precipitation reports was necessary to ensure complete sets of comparative values for all stations.

Primarily under consideration are forest environments. Consequently, the special problems in acquisition of data for forestry stations arise. Temperature extremes, precipitation, wind velocity and direction, and relative humidity are observed twice daily. However, when the reports are coded for the computer cards, the respective columns for wind and humidity are vacant. This would seem reasonable, since only two observations per day are taken and thereby fail to define accurately 24-hour mean values. Temperature and precipitation totals with the occasional inclusion of growing-degree days and mean temperatures are therefore characteristics of tower observations.

Processing of Data

Unique problems in machine processing of the computer cards were encountered.

Combinations of alphanumeric (L and C) and numeric characters

forced total conversion of the original data bank to a data set composed entirely of numeric values. The letter L refers to precipitation totals on the day in question such that if rain did fall it was accumulated on the next day's total. In the process of conversion the L was simply eliminated. On the other hand, the letter C indicates that rain did fall on that day but the next day's total includes the amount. Written into the analysis programs was the equal division of this total rainfall for both or all days under consideration. The letter T indicating Trace amounts of rainfall of less than .01 inches was again eliminated in data-set transfers. As the final stage, the 160,000 data-set card file was checked and rechecked to ensure validity in conversion.

In addition, numerous unexpected punching errors in the supplied cards terminated execution of the normal conversion routine, thus necessitating special programs to be written and incorporated into the mainline conversion program. This apparent lack of Quality Control of pre-punched data demands special processing to ensure compatability of the variables with the data storage system.

Errors in monthly mean values when compared to monthly values in the Monthly Record become obvious. Maximum and minimum temperature values are rounded off and represented as integers on the computer cards. Subsequent mean daily temperatures are represented in integer form in the conversion programs but were carried to one decimal place for the calculations of monthly mean daily temperatures.

Monthly Record (Department of Transport, Meteorological Branch), on the other hand, calculates the monthly means from the average of the monthly maximum and minimum temperatures. Consequently,

the resulting differences in the computed means of the order of less thean ±0.3°F were not of a significant magnitude to invalidate the calculations of results. Illustration of the Monthly Record mean temperatures as compared with the calculated mean temperatures for Fairview 1966 appears in Table 4.1.

Table 4.1

Fairview 1966

MONTH	MONTHLY RECORD MONTHLY MEAN TEMP.	CALCULATED MONTHLY MEAN TEMP.	RESIDUALS
April	30.9°F	30.7°F	-0.2°F
May	51.4	51.2	-0.2
June	54.5	54.2	-0.3
July	59.0	58.7	-0.3
August	57.7	57.5	-0.2
September	52.9	52.6	-0.3
October	37.0	36.7	-0.3

Data Generation

The need for new and complete data sets arises with the inclusion of Alberta Forestry tower observations. These stations often do not open until approximately the first of May and often close just after the end of September. The period of operation is dependent upon the fire conditions of the year. Therefore only five months of possible data reporting can be assumed. Thusly,

the associated stations - first-order and climate - must also conform to this time period - May to September. High frequencies of the occurrence of missing data within this 5-month period are also to be expected. Isolation coupled with breakage of instruments at the towers often results in complete months without reports.

Most tower stations received minimum, maximum and wet-bulb thermometers in 1962. At the commencement of the project analysis in January, it was outlined that only actual observations per five-month year would be utilized in the climatic grouping procedure. However, if this trend of analysis were followed, approximately 15 of the selected 54 stations would be useful. Therefore, the application of polynomial regression estimation techniques was able not only to complete these non-continuous data sets but also to generate additional information such that each of the stations has an associated five-month data base extending from 1954 to 1968.

Polynomial Regression Analysis

Least squares approximations to higher orders are referred to as polynomials of the first, second, third, to the nth degree. The objective of this phase is the generation of maximum and minimum temperatures for days with data missing within the prescribed time period.

In all cases, for all combinations of stations, third degree estimation of temperature extremes was found to be statistically sufficient. Simple linear regression is unable to provide adequate accuracy for prediction purposes.

Figure 4.3 illustrates a plot of the observed values at

Grande Prairie minus the associated polynomial predicted values for Fairview. This difference in comparison to the temperature values illustrates the non-linear curves for maximum and minimum temperatures. For the purposes of predicting Fairview, Grande Prairie was the independent variable with Fairview being the dependent variable in the dependent data set.

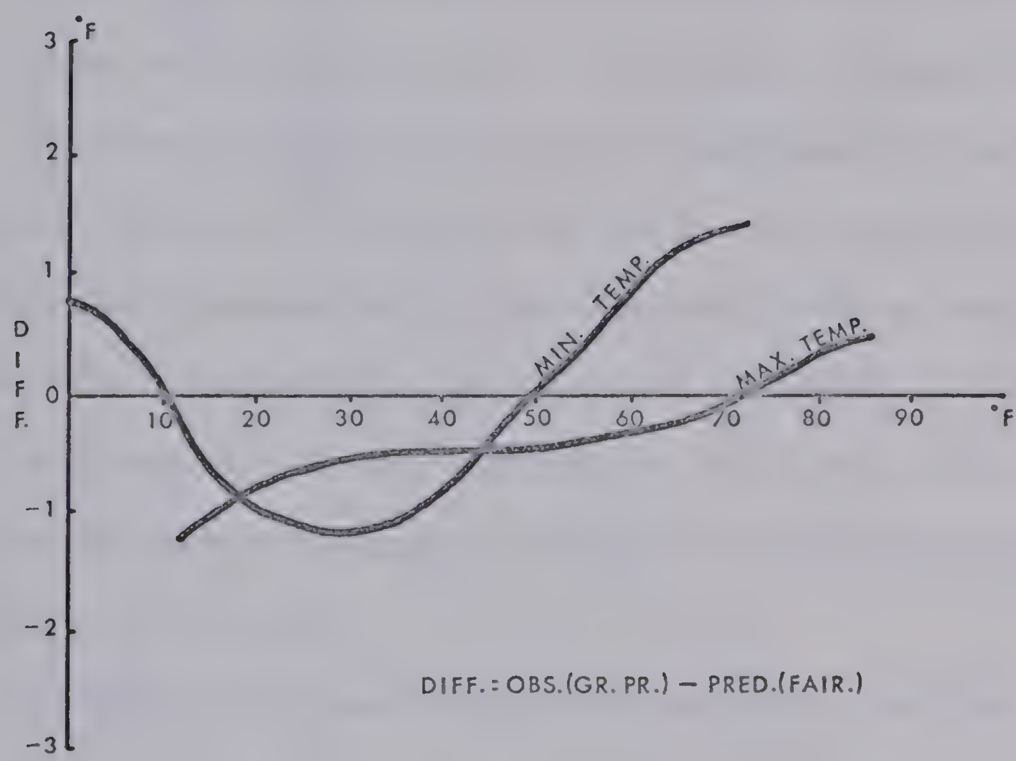


Figure 4.3
Polynomial Regression - Difference Between Grande Prairie and Fairview for the Months April to October for Observed and Predicted Minimum and Maximum Temperatures

The differences found in the maximum temperature curve are approximately linear for the interval 30 to 60°F. The data base used to generate each of these curves consisted primarily of values ranging from 30 to 60°F in the maximum temperatures and 10 to 40°F in the minimum temperatures. The curvilinear effects at the ends of each line arise because of a lack of frequency of occurrence of those

temperatures. The above curves are derived from the prediction equations for the months April to October only.

Relationships between the observed and predicted values of maximum temperature for Fairview, with Grande Prairie as the base station, are shown in Figure 4.4. B denotes the concurrence of two values - predicted and/or observed - plotted at the same coordinate; O denotes the plotting of the observed values and P the predicted values. This close correlation of observed and predicted values is also quite characteristic in the prediction of minimum temperatures.

In order to explain and test the usefulness of the technique better, an artificial "hole" was created in the data set for Fairview. The independent variable within the dependent data set was Grande Prairie. The dependent data set consisted of 500 daily observations from both Grande Prairie and Fairview for the months April to October. The resulting prediction equations for both maximum and minimum temperatures were found.

Generally, the equation is represented in the form:

$$Y = \alpha + B_1 x + B_2 x^2 + \dots + B_k x^k + e$$

where Y is the dependent variable (Fairview daily max. temperature), α is the Y-intercept, B_i $(i = 1, \dots k)$ are the regression coefficients, x is the independent variable (Grande Prairie daily max. temperature), and e is the standard error of the regression coefficient.

The resulting predicted values for the year 1967 for Fairview in comparison with the values presented in <u>Monthly Record</u> are shown in Table 4.2.

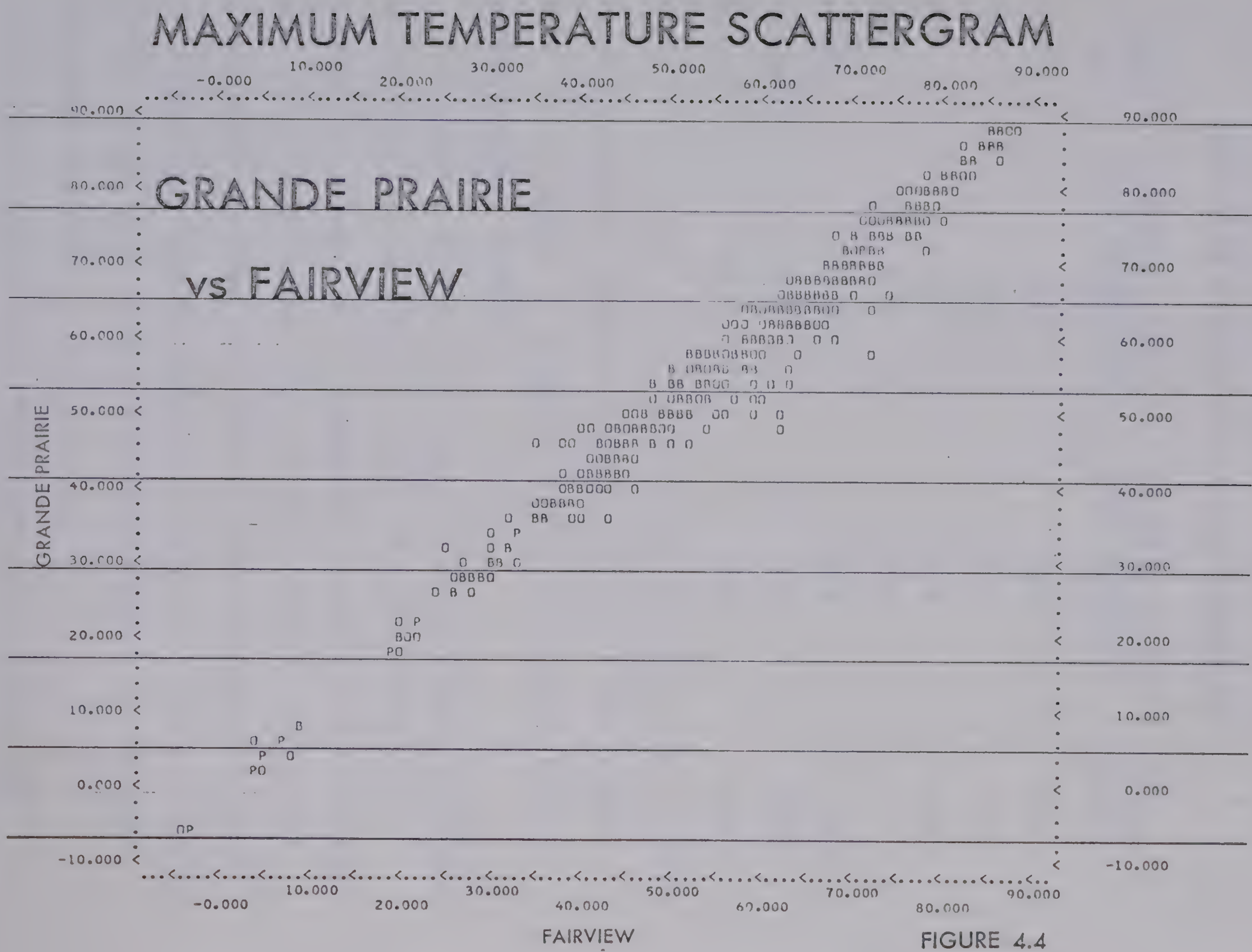

MAXIMUM TEMPERATURE SCATTERGRAM
GRANDE PRAIRIE
vs FAIRVIEW
GRANDE PRAIRIE
FAIRVIEW

FIGURE 4.4

Table 4.2

Observed vs Predicted Values for Fairview, 1967

MONTH	OBSERVED - MONTHLY MEAN TEMPERATURE	PREDICTED MONTHLY MEAN TEMPERATURE	RESIDUALS
April	31.5	32.1	+0.6
May	49.0	49.5	+0.5
June	56.8	57.6	+0.8
July	61.7	61.4	-0.3
August	64.2	63.9	-0.3
September	56.2	56.8	+0.6
October	39.5	40.4	+0.9

Considering initial discrepancies of ±0.3°F, the residual value of ±0.9 appears to be sufficiently accurate for the purposes of macroclimatic research.

Applying this estimation technique to the complete study area, six base stations, each having complete 15-year daily-data sets, were chosen. Comparison, via polynomial regression of the remaining stations to Grande Prairie, Edson, Meanook, Ranfurly, High Prairie or Whitecourt, provided two polynomial prediction equations per pair of comparisons. Reapplication of these equations to the base stations thereby generated the required new data to complete the previously incomplete data sets.

A null hypothesis to test the predicted minus the observed values was established such that there is no significant difference

at the 99.9 per cent significance level. By applying analysis of variance tests to each pair of prediction stations, only one station failed to satisfy these criteria. Carrot Creek versus the base station Edson proved significant only at the 95 per cent level. The resulting residuals between observed and predicted temperature values of the order of ±12°F eliminated it from further analysis. The number of data base stations now is equal to 53.

Attempts at precipitation estimation proved unreliable and distinctly faulty. Comparison on a daily basis of both rain, no-rain reports did not work. Owing to the discontinuous nature of precipitation occurrence, the regression coefficients were wrongly weighted due to the higher frequency of no-rain days as opposed to the frequency of rain days. However, since the stations have been reporting precipitation for 12 years or more, resulting averages were taken to be representative of the study period 1954-1968.

Investigations into the generation of equations for the prediction of relative humidity as a function of maximum and minimum temperatures also did not work. In theory, moisture estimation is dependent more upon the type of air mass, cloud cover, precipitation occurrence, and vegetation types than simply temperature.

However, the Agrometeorology Branch of the Department of Agriculture postulated the prediction of mean daily dew-point at a number of agricultural stations across Canada. The equation is presented as:

$$T_d = -12.58 + 0.52\ \mathrm{MIN} + 0.92\ \mathrm{MAX} - .005\ \mathrm{MAX}^2$$

where T_d is the mean daily dew point temperature (°F), MIN is the minimum temperature (°F) and MAX is the maximum temperature (°F).

Following the same method of analysis for moisture estimation, polynomial prediction equations were calculated for relative humidity as a function of temperature. Figure 4.5 illustrates the scattergraph illustrating the observed and predicted values for Grande Prairie. The x-axis represents daily minimum temperature and the y-axis represents daily maximum relative humidity. The level of significance, again determined by applying analysis of variance tests, was found for fourth degree polynomial estimation to be less than 85 per cent.

In conclusion, the technique of temperature extreme estimation proved statistically sound, enabling formulation of complete data records of temperature per station.

MINIMUM RELATIVE HUMIDITY vs MAXIMUM TEMPERATURE

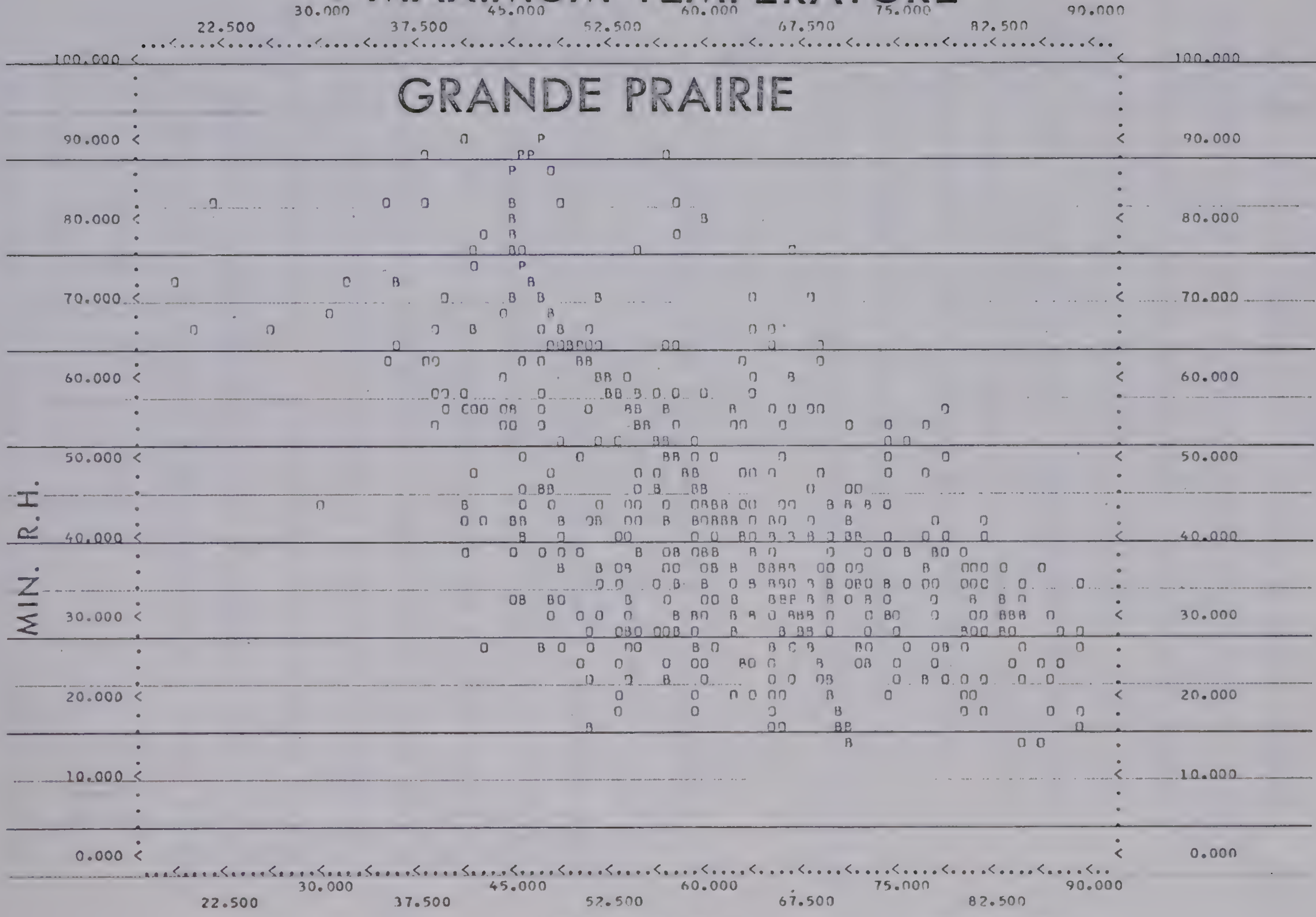


FIGURE 4.5

Chapter 5

Climate of the Study Area

Dynamic climatic variability resulting in valid climatic zones identifies areas with differing values for human activities. The interrelationships among temperature, moisture and sunlight, each affected differently by underlying vegetation, soils and topography, result in unique ways to form homogeneous climatic areas. Characteristics of the study area in terms of thermal, moisture and radiational fluctuations are outlined in this chapter. In most cases, the maps are self-explanatory, but brief notes on the extremes found in various areas will be alluded to.

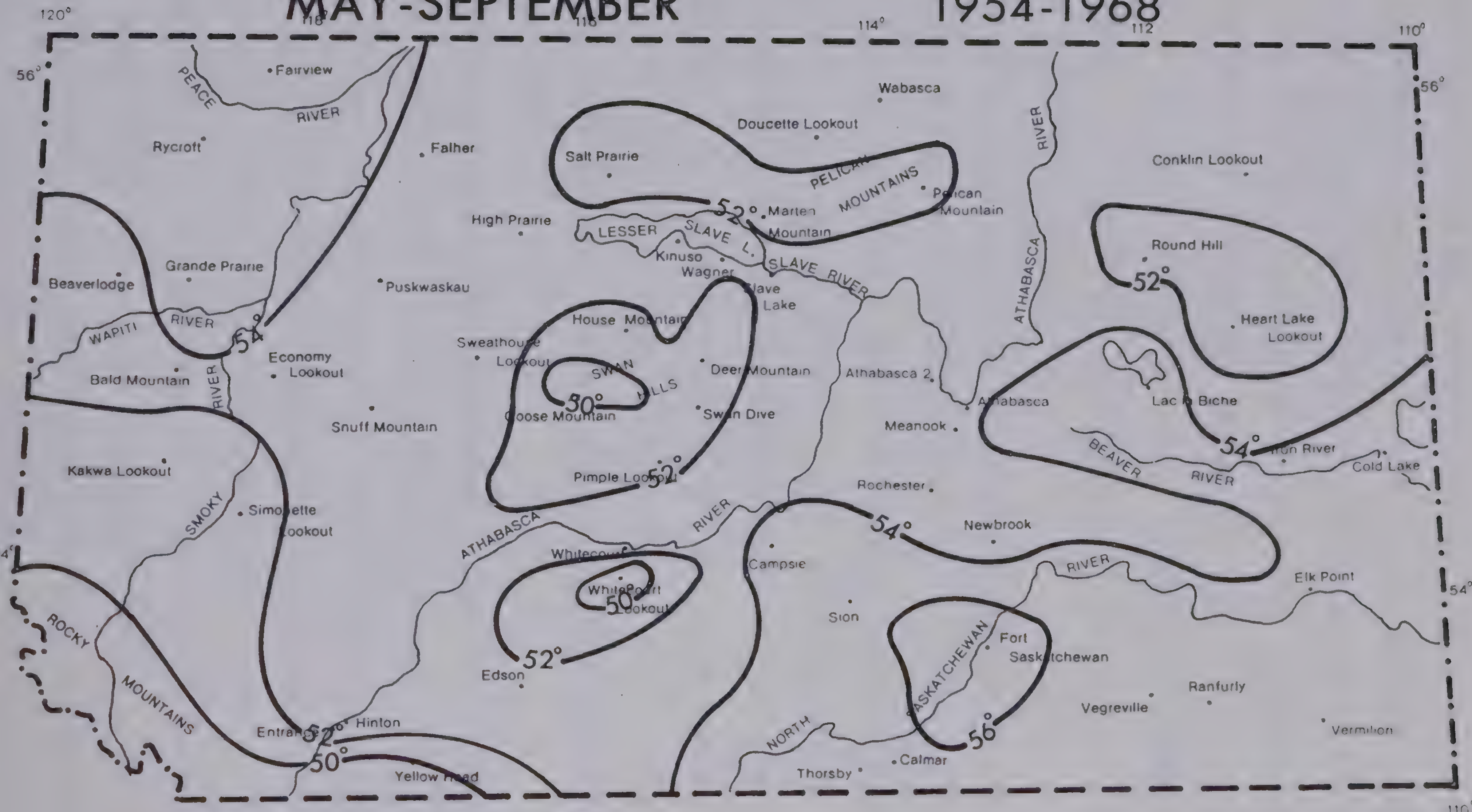
Temperature

Thermal sensitivity aids in regulating areal suitability and the processes of biological adaptation. The temperature values presented are calculated from daily reports supplied by the Department of Transport or Alberta Forestry observing sites. Stevenson Screen instruments, at four and one-half feet above the ground measure maximum, minimum, present and wet-bulb temperatures. Based upon these daily values, mean monthly normals for the years 1954 to 1968, inclusive, were then calculated. These values serve as input for the following analysis. Presented herein are the seasonal means for mean, maximum and minimum temperatures. The season, in all cases, is taken to be May 1st to September 30th, inclusive.

Regional comparison between stations is provided in Figure 5.1 of mean daily temperature for the season. Higher temperatures are experienced in the southeast and northwest of the study area as

MEAN DAILY TEMPERATURE

MAY-SEPTEMBER 1954-1968



VALUES IN DEGREES FAHRENHEIT

FIGURE 5.1

0 20 40 60 80 100 Miles

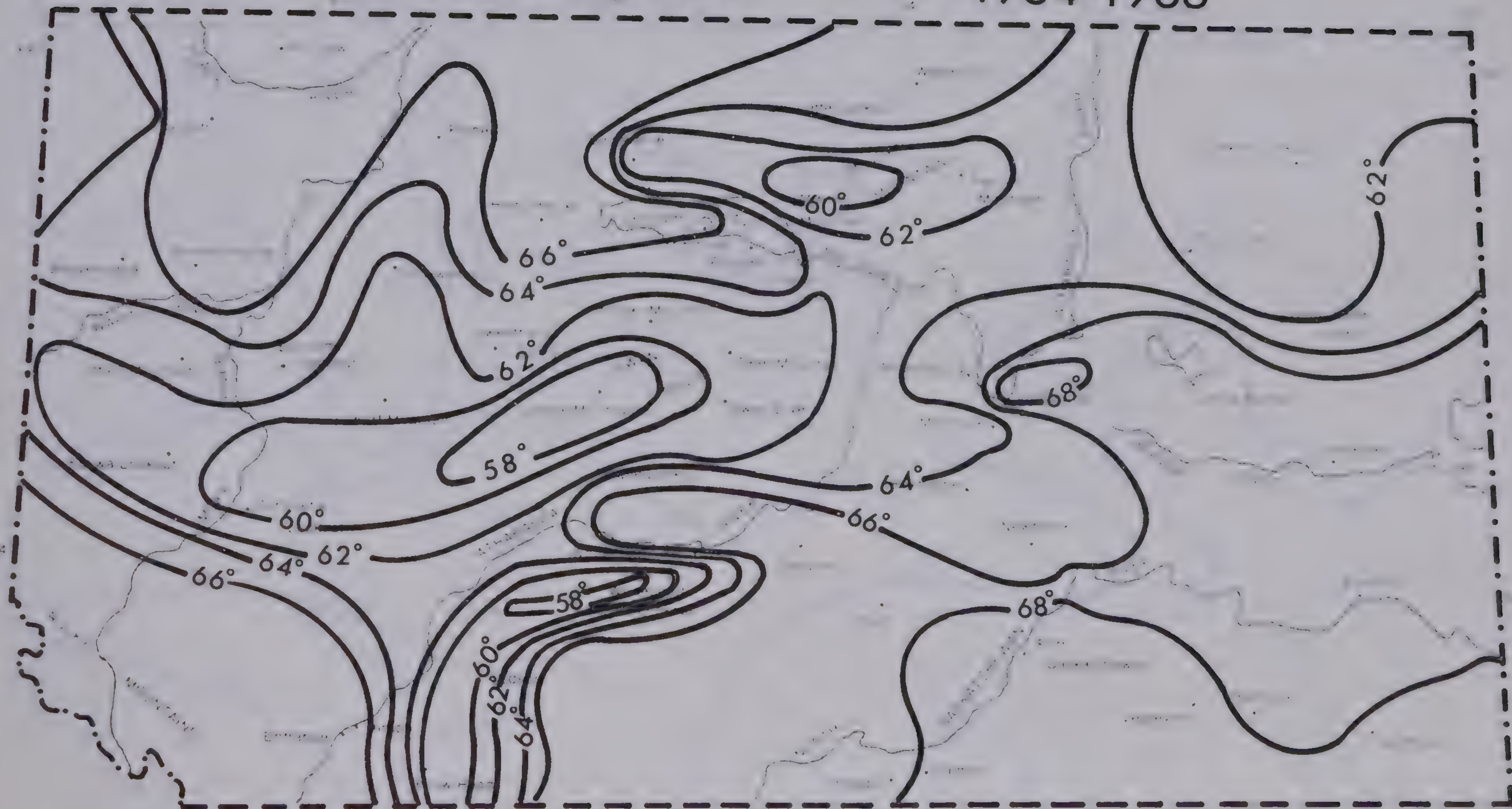
compared to the central and southwest portions. The close proximity of the southwest to the Rocky Mountains and the higher elevations of the central area (Swan Hills) account for the lower seasonal temperatures. The two areas with the higher temperatures are characterized by better agricultural land and more productive soils.

The rest of the region is primarily forest underlain with grey-wooded soils. Lower productive soils are found, therefore, in areas of lower temperatures.

Figure 5.2 gives the mean daily maximum temperature for the study area. Higher maximums are located in the southeast and northwest than in the central regions. Higher temperatures in the southwest, as indicated by stations Hinton and Entrance, are a result of micrometeorological increases due to the presence of the location of the stations in the Athabasca River Valley. The valley acts as a heat source during the daytime and a cold source during the nighttime. The resulting observations, therefore, are only indicative of the river valley.

The mean daily minimum temperatures, Figure 5.3, again show higher values in the northwest and southeast of the area. The stations, Hinton and Entrance indicate lower minimum temperatures, again, a result of the downslope drainage into the Athabasca River Valley at night. Hayter shows that the values for Meanook are high and local in nature, not representative of the general surrounding area. Using a mobile thermo dew-point recorder, Hayter in 1969 investigated this localized climate about Meanook in a study of frost perception in northeast Alberta. Consequently, in the case of Meanook, topography plays an extremely important role in the variation of

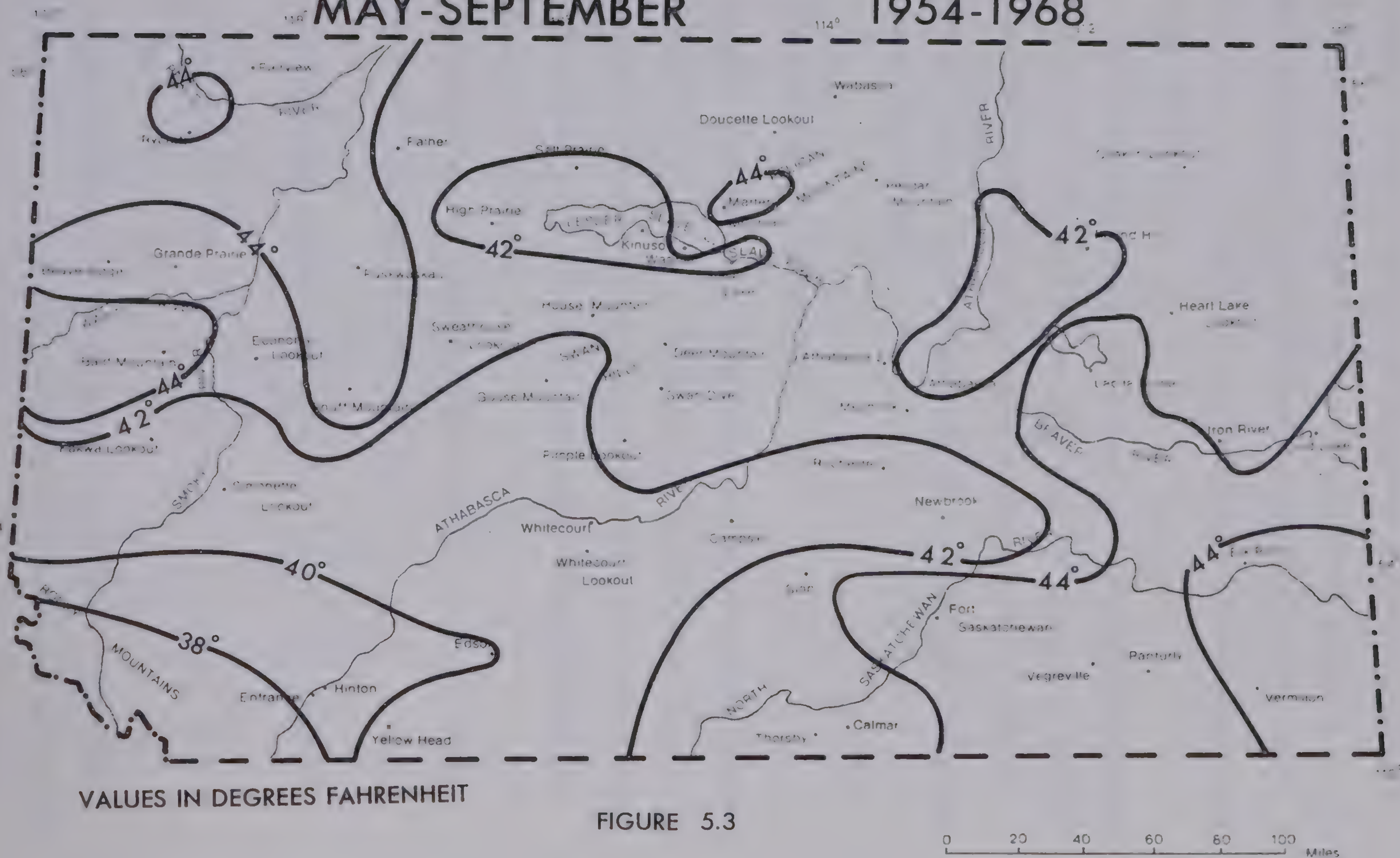
MEAN DAILY MAXIMUM TEMPERATURE
MAY-SEPTEMBER 1954-1968



VALUES IN DEGREES FAHRENHEIT

FIGURE 5.2

MEAN DAILY MINIMUM TEMPERATURE
MAY-SEPTEMBER 1954-1968



VALUES IN DEGREES FAHRENHEIT

FIGURE 5.3

minimum temperatures. Broad generalization of the region indicates that the better agricultural land has minimum temperatures above 44°F with the lesser agricultural land (<50% cultivated) above 42°F. The associated forested environments are below 42°F in the seasonal mean minimum temperatures.

The micrometeorological variations associated with the river valley influence at stations Hinton, Entrance and Meanook illustrate the one possible error within any regionalization technique using only point source data. This should be kept in mind when interpretation of these maps is made.

Standard Deviations of Temperature

Monthly mean values of temperature can be misleading in the interpretation of the climatic variability for the month. To provide an indication of the variability in daily temperature, monthly mean standard deviations for each station for mean, maximum and minimum temperatures were computed.

The values provided in the accompanying Table 5.1, were calculated from daily mean temperatures by:

$$\text{Standard Deviation}^2 = \left(\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i \right)^2}{N} \right) \Big/ (N-1)$$

where x_i is the mean temperature for the day i, and N is the number of days in the month.

Regional maximums and minimums of the standard deviations are herein described. Do higher elevation stations experience higher standard deviations as opposed to lower elevation stations? From

the accompanying Table 5.1, no apparent increase in standard deviations of temperature is apparent with increasing elevation. In fact, the uniformity of the standard deviation values among the stations tends to indicate the lack of abnormal temperature extremes within the study region.

Differences between some point stations of the order of ±5.6°F are noted in Table 5.1 The June maximum temperature deviation for Round Hill Lookout is ±12.4°F in comparison to the June deviation at Snuff Mountain of ±6.8°F. These spot variabilities do not, however, indicate a general trend - the Rycroft June deviation is found to be ±6.9°F. However, one overall trend is that the minimum deviation of temperature - mean, maximum and minimum - usually occurs in the month of July. Similar lower deviation values are also experienced for the months of June and August resulting in a 3-month minimum for June-July-August. This would appear to be coupled with the period of maximum in-coming solar radiation. Beaverlodge, Alberta, serves as an appropriate example of the stablizing influence of the solar radiation. The May maximum temperature deviation is ±10.9°F as compared to the July maximum deviation of ±7.4°F.

Table 5.1 summarizes the monthly standard deviation values for maximum, minimum and mean temperatures. The similarity in the station's extreme values is illustrated by the deviations being normally less than ±11.0°F. Accompanied with any generality, however, are exceptions. The exceptions in this case are Snuff Mountain, Athabasca 2, Meanook and Round Hill.

Table 5.1

Standard Deviations of the Monthly Temperatures for the Stations of the Study Area 1954-1968

STATION	MEAN TEMPERATURE					MAXIMUM TEMPERATURE					MINIMUM TEMPERATURE				
	MAY	JUNE	JULY	AUGUST	SEPTEMBER	MAY	JUNE	JULY	AUGUST	SEPTEMBER	MAY	JUNE	JULY	AUGUST	SEPTEMBER
Athabasca	7.2	6.3	5.0	5.1	6.3	9.8	8.6	6.7	7.3	8.8	7.0	6.3	5.5	5.4	6.1
Athabasca 2	8.6	6.5	6.3	5.5	6.6	11.6	9.1	8.6	7.8	9.1	7.7	6.1	5.9	5.2	6.5
Bald Mtn. Lo.	7.6	5.2	5.1	5.1	6.7	10.0	7.3	7.3	7.3	8.9	6.8	5.3	4.7	5.1	6.8
Beaverlodge	7.5	5.1	5.1	5.1	6.6	10.2	7.3	7.4	7.5	9.3	6.5	5.3	5.1	5.1	6.6
Calmar	7.3	5.1	5.1	5.0	6.6	9.8	7.3	6.9	7.4	9.3	6.7	5.3	5.0	5.0	6.4
Campsie	7.1	4.8	5.5	5.6	6.1	10.2	7.5	7.7	8.2	8.9	7.5	6.0	6.1	6.5	7.4
Cold Lake	7.7	5.7	5.2	5.1	6.7	9.8	7.9	7.0	7.1	9.1	7.2	5.6	5.2	5.1	6.5
Conklin Lookout	8.6	7.1	6.1	5.5	6.9	10.9	9.0	7.9	6.8	8.9	8.2	7.1	5.8	5.7	6.5
Deer Mtn. Lo.	7.5	5.2	5.1	5.2	6.5	10.4	7.7	7.5	7.7	9.0	6.7	4.9	4.5	4.8	6.5
Doucette Lo.	8.0	5.4	4.9	5.6	6.4	10.3	8.0	6.9	8.1	8.3	7.8	5.1	4.7	5.2	7.0
Economy Lo.	7.5	4.9	4.8	4.7	6.5	10.0	6.9	6.9	7.0	9.1	6.4	4.7	4.2	4.3	6.2
Edson	7.0	4.8	5.5	5.1	6.2	10.5	7.5	7.6	7.8	9.5	6.7	5.7	6.1	5.4	6.4
Elk Point	8.2	5.3	5.7	5.3	7.0	10.7	7.7	7.5	7.5	9.8	8.2	6.0	6.5	6.3	7.6
Entrance	6.4	4.7	5.3	5.0	5.9	9.8	7.1	7.6	7.9	8.8	5.9	5.5	5.5	5.0	6.0
Fairview	7.8	5.3	5.1	5.2	6.7	9.8	7.0	7.1	7.3	8.8	6.8	5.1	4.4	4.7	6.3
Falher	7.1	4.7	4.6	5.2	6.2	9.6	7.2	6.7	8.0	8.6	6.7	5.0	4.7	4.7	6.2
Ft. Sask.	7.6	5.2	5.2	5.2	6.8	10.0	7.6	7.1	7.5	9.5	7.1	5.3	5.0	5.1	6.4
Goose Mtn. Lo.	7.1	5.3	5.3	5.3	6.2	10.0	7.7	7.6	7.8	8.7	6.4	5.0	4.8	4.9	6.3
Grande Prairie	7.4	5.0	4.9	4.9	6.4	9.9	7.1	7.2	7.2	8.8	6.6	5.1	4.6	5.1	6.6
Heart Lake	8.3	6.3	5.5	5.5	7.2	9.9	7.7	6.6	6.8	9.0	8.4	7.0	5.8	5.8	6.9
High Prairie	7.7	5.6	6.2	5.7	6.2	10.2	8.0	8.7	8.3	8.2	7.5	6.0	6.8	5.5	6.9
Hinton	6.7	4.9	5.2	5.0	6.2	10.1	7.5	7.6	8.1	9.3	6.5	6.0	6.0	5.3	6.7
House Mtn. Lo.	7.1	5.3	5.0	5.3	6.5	10.3	7.8	7.3	7.6	9.0	6.4	5.2	4.6	5.1	6.5
Iron River	7.5	5.2	4.9	5.0	6.3	9.6	7.3	6.6	7.0	8.6	7.1	5.3	5.4	5.3	6.6
Kakwa	7.3	5.3	5.4	5.1	6.6	9.9	7.6	8.0	7.7	8.9	6.2	4.9	4.5	4.7	6.6
Kinuso	7.4	5.3	5.7	5.3	5.9	9.7	7.9	8.7	8.2	7.9	7.4	5.5	5.5	4.8	6.7
Lac la Biche	7.7	5.3	4.9	5.0	6.4	10.0	7.5	6.7	7.2	8.3	7.3	5.5	5.0	5.1	6.4
Marten Mtn. Lo.	7.6	5.4	4.9	5.4	6.6	9.3	7.4	6.2	7.5	8.0	8.0	5.1	5.1	4.9	7.2
Meanook	10.1	9.6	7.9	6.2	7.1	13.0	12.8	10.6	7.8	9.4	9.5	8.9	7.1	6.1	6.5
Newbrook	7.8	6.2	6.9	6.9	5.2	10.4	8.6	9.7	7.1	9.1	7.6	6.7	6.4	6.2	7.0
Pelican Mtn.	7.5	5.5	4.8	5.5	6.2	10.1	7.7	6.6	7.8	8.3	6.4	5.0	4.4	5.1	6.0
Pimple Lo.	7.0	5.0	4.8	5.1	6.2	10.3	7.4	6.9	7.4	8.6	5.8	4.8	4.7	4.9	6.1
Puskwaskau	7.3	5.2	4.8	5.3	6.1	10.0	7.1	6.5	7.6	8.2	6.3	4.8	4.2	4.5	5.6
Ranfurly	7.8	5.6	5.2	5.4	7.3	10.1	8.1	7.3	7.8	9.8	7.3	5.5	5.1	5.2	6.8
Rochester	7.8	7.5	6.4	5.4	6.8	10.4	9.5	8.6	7.7	9.2	7.2	7.8	6.4	5.6	6.8
Round Hill Lo.	9.5	8.7	7.6	5.8	6.7	12.7	12.4	11.3	7.5	8.7	8.5	7.7	5.7	5.8	6.2
Rycroft	7.4	5.0	5.0	5.1	6.7	10.1	6.9	7.1	7.4	9.2	7.2	5.9	5.4	5.8	7.2
Salt Prairie Lo.	7.3	5.3	5.1	5.4	6.0	9.9	7.7	6.7	7.8	8.1	6.7	5.1	5.3	5.2	5.9
Simonette Lo.	7.0	5.3	5.5	5.4	6.4	9.8	7.7	8.0	7.9	8.8	5.7	4.8	4.7	5.0	6.1
Sion	7.0	4.8	4.7	4.7	6.0	9.8	7.4	7.0	7.1	8.7	6.5	5.0	4.5	4.6	6.0
Slave Lake	7.1	4.8	5.5	4.6	5.6	9.6	6.6	8.0	6.5	7.9	6.9	5.9	6.2	5.5	6.2
Snuff Mtn. Lo.	7.3	4.9	4.7	4.7	6.5	9.7	6.8	6.5	6.6	8.7	6.5	5.0	4.6	4.8	6.5
Swan Dive Lo.	7.3	5.4	5.5	5.6	6.9	10.4	7.8	7.6	8.0	9.5	6.2	5.1	5.1	5.1	6.4
Sweathouse Lo.	7.2	4.8	4.6	4.8	6.3	10.7	7.7	7.2	7.3	9.2	6.0	4.4	4.0	4.2	5.9
Thorsby	7.3	5.1	4.6	4.8	6.7	9.6	7.6	6.7	7.3	9.2	6.6	4.8	4.2	4.4	6.2
Vegreville	7.5	5.0	5.1	5.3	6.5	10.1	7.4	7.4	7.8	9.7	6.9	5.2	5.3	5.1	6.1
Vermilion	7.6	5.4	5.1	5.1	7.0	10.1	7.9	7.3	7.7	9.9	7.5	5.9	5.6	5.3	6.9
Wabasca R.S.	7.9	5.4	5.7	5.4	6.3	10.2	7.3	8.0	7.8	8.2	7.9	6.0	6.2	5.4	7.0
Wagner	7.2	4.8	4.6	4.5	6.1	9.5	6.6	6.2	6.4	7.9	7.1	5.6	5.1	5.1	6.6
Whitecourt Lo.	6.3	4.9	4.6	5.9	6.4	6.9	5.5	4.9	5.5	7.1	7.2	5.7	5.4	5.6	7.0
Whitecourt	7.2	5.0	4.9	5.1	6.2	10.6	7.8	7.3	7.6	9.0	7.2	5.9	5.5	5.8	7.0
Yellowhead Lo.	7.1	5.2	5.7	5.4	6.5	10.6	7.9	7.9	8.2	9.7	6.2	5.2	5.7	5.0	6.2

Precipitation

Temperature variations can severely damage and limit vegetational growth; so also can the lack of adequate precipitation. Isolines of seasonal precipitation (May 1st to September 30th) are shown in Figure 5.4 Maximum amounts (>16 inches) for the season are found usually at higher elevations within the study area, with the minimum amounts (<12 inches) located in the northwest and southeast regions - lower elevations. Consequently, associated with the lower elevations are both minimum precipitation and maximum mean daily temperatures. Illustration of the results of topographical influence upon the precipitation patterns is noted in the comparison of Goose Mountain and High Prairie stations. Goose Mountain Lookout at an elevation of 4500 feet has a seasonal rainfall value of 19.0 inches as compared to High Prairie at an elevation of 1958 feet with a seasonal total of 10.0 inches. This increase of nine inches of precipitation is associated with an elevational increase of only 2642 feet.

But what are the characteristics of rainfall? Can we expect the same intensity per month for both low and high elevation stations? In order to answer these questions, computation of the mean numbers of days of precipitation above 5 base levels per month was made and are illustrated in the accompanying Figures 5.5 to 5.7. Three stations serve as being representative of the study area stations. Grande Prairie at an elevation of 2190 feet typifies the northwest portion, whereas Elk Point at an elevation of 1920 feet represents the southeast portion of the study area. The remaining higher elevation

MAY-SEPTEMBER PRECIPITATION

1954-1968

VALUES IN INCHES

FIGURE 5.4

MEAN FREQUENCY OF PRECIPITATION INTENSITY

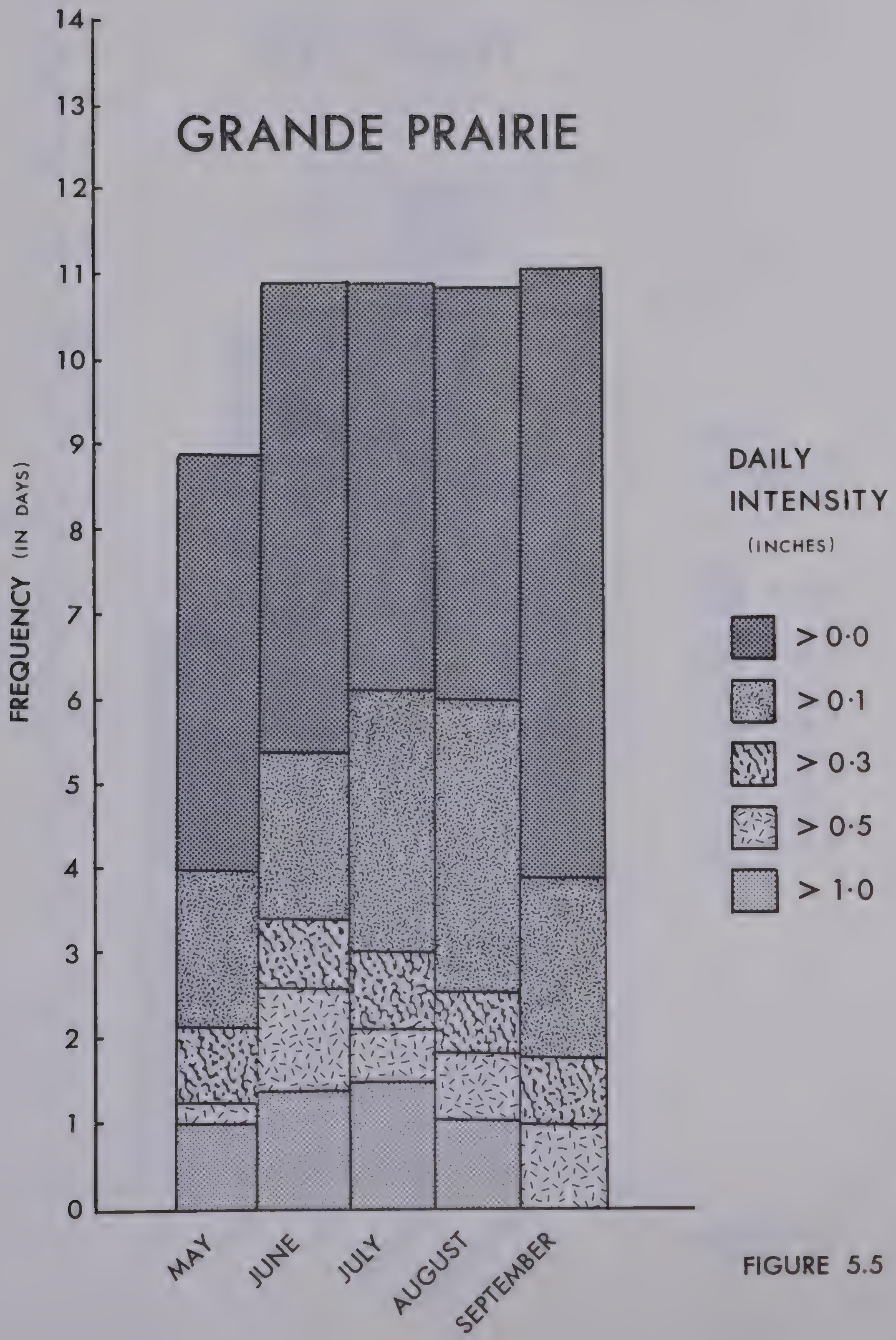


FIGURE 5.5

MEAN FREQUENCY OF PRECIPITATION INTENSITY

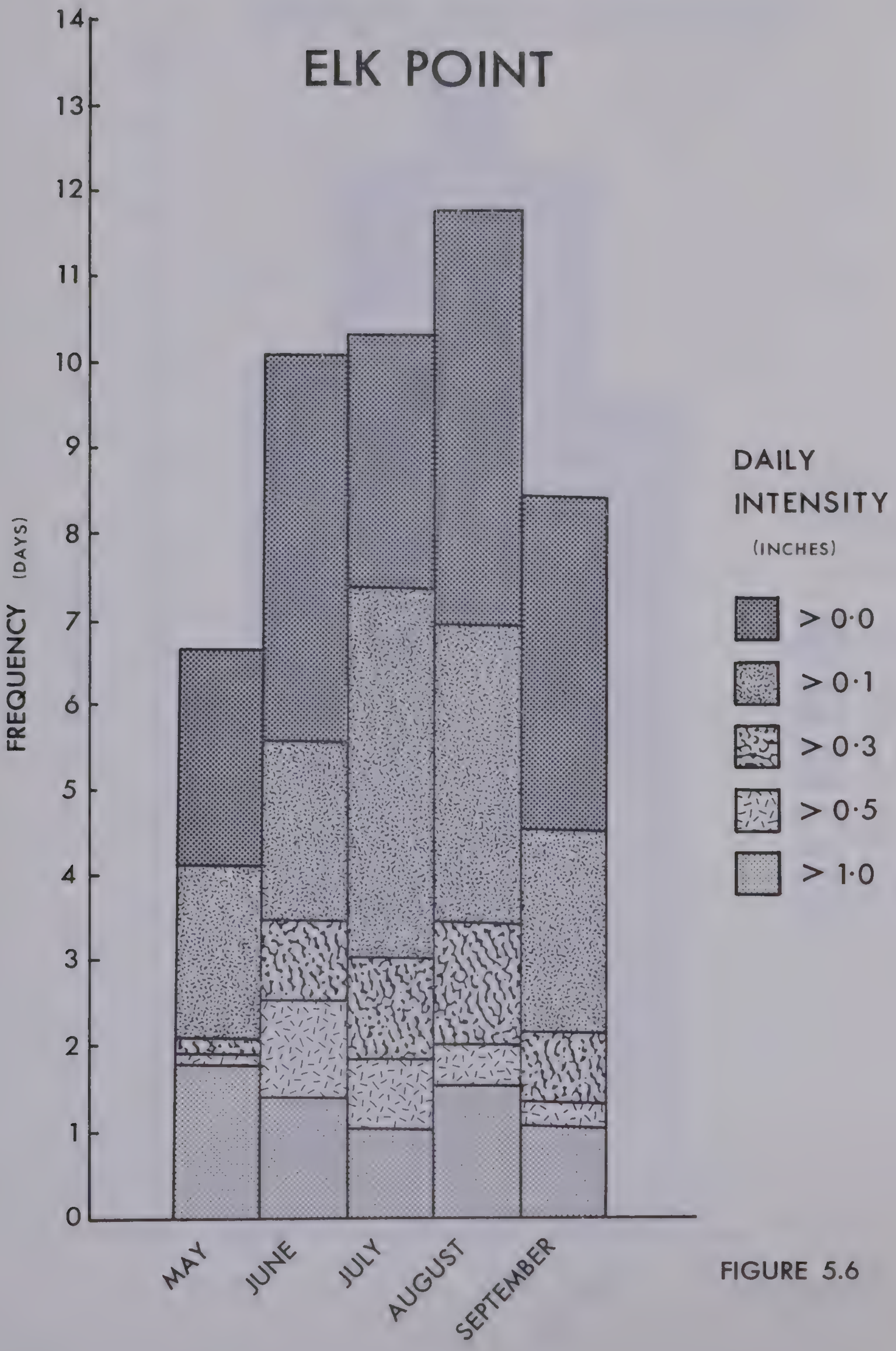


FIGURE 5.6

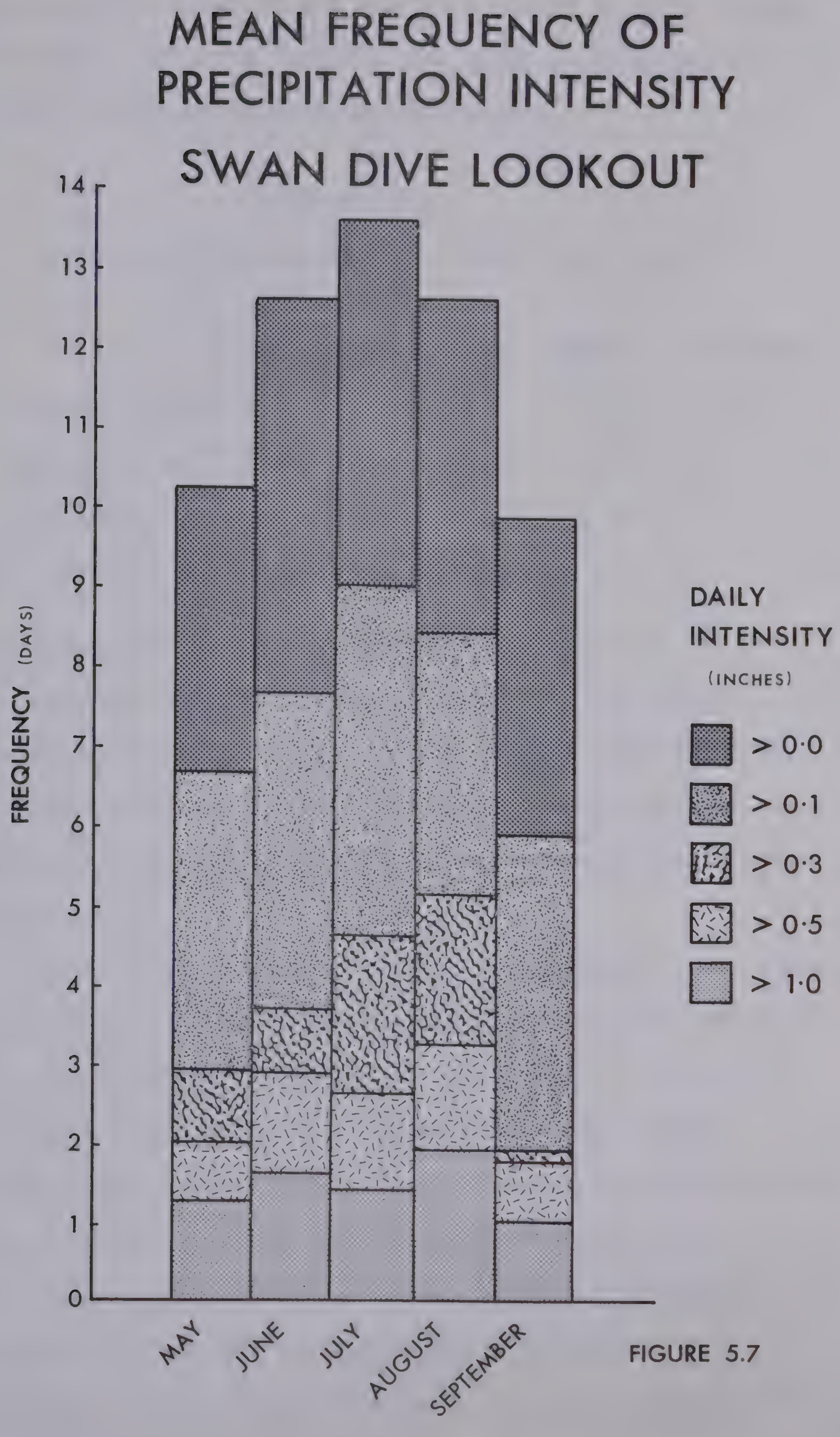

MEAN FREQUENCY OF
PRECIPITATION INTENSITY
SWAN DIVE LOOKOUT
FREQUENCY (DAYS)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
MAY
JUNE
JULY
AUGUST
SEPTEMBER
DAILY
INTENSITY
(INCHES)
> 0·0
> 0·1
> 0·3
> 0·5
> 1·0

FIGURE 5.7

stations are represented by the Swan Dive Lookout Tower at a height of 4174 feet. Table 5.2 indicates the total amount of precipitation per month for each of the above three stations.

Table 5.2

Mean monthly precipitation - 1954-1968 (inches)

	May	June	July	August	September
Grande Prairie	1.5	3.0	2.4	2.4	1.2
Swan Dive	2.5	3.5	4.4	3.8	1.7
Elk Point	1.5	2.9	2.9	2.9	1.9

Grande Prairie indicates a relative maximum in June with the general maximum occurring during June, July and August. This general maximum is typical of all three stations, most notably Elk Point. The Swan Dive Lookout, in contrast, indicates a maximum precipitation in July again with the general monthly maximums occurring in June-July-August.

Reference to Figures 5.5 to 5.7 indicates again this general June-July-August maximum for the mean number of days per month above both 0.0 and 0.1 inches. Above these base levels - 0.0 and 0.1 - the frequency curves are altered dependent upon the elevation. The lower stations - Grande Prairie and Elk Point indicate a relative uniformity in the curves for the frequency above .3, .5, and 1.0 inches. However, the difference between the August frequency at the .30 inch level of 5.1 and the September frequency of 2.0 illustrates this elevational difference. But still, the difference

between 5 days and 3 days per month is not of any great significance to the vegetational growth rates. In conclusion, therefore, the intensity of rainfall at the stations within the study area exhibits maximums during June, July and August. On most days with rain, rainfall expected is of the order of less than .30 inches per day. These findings, in view of the statistical grouping climatic classification, are peripheral to the results; however, they do provide a better idea of the characteristics of the moisture patterns provided for the study area.

Frost-Free Period

The occurrence of frost (minimum temperatures less than 32°F) can severely inhibit, damage and/or kill the vegetation within a region. Frost sensitivity and consequent susceptibility to permanent damage occurs in many tree species and crop varieties.

Spatial patterns of the frost-free days are shown in Figure 5.8. Frost-free period is the number of days between the last occurrence of frost in the spring and the first occurrence of frost in the fall. Maximum frost-free period (>120 days) is found in the northwest portion of the area of study, again, in the environs of Grande Prairie. Minimum frost-free period (<80 days) is found in proximity to the Rocky Mountains, the Whitecourt area, and the Newbrook area. Mean dates of the last occurrence of 32°F in the spring are shown in Table 5.3. Likewise, the mean dates of the first occurrence of 32°F in the fall are shown for each of the study area stations.

Killing frost-free days are also illustrated in Figure 5.9. Killing frost-free period is the number of days between the last

MEAN LENGTH OF PERIOD FROM LAST OCCURRENCE OF 32° F IN SPRING TO FIRST OCCURRENCE IN FALL
1954-1968

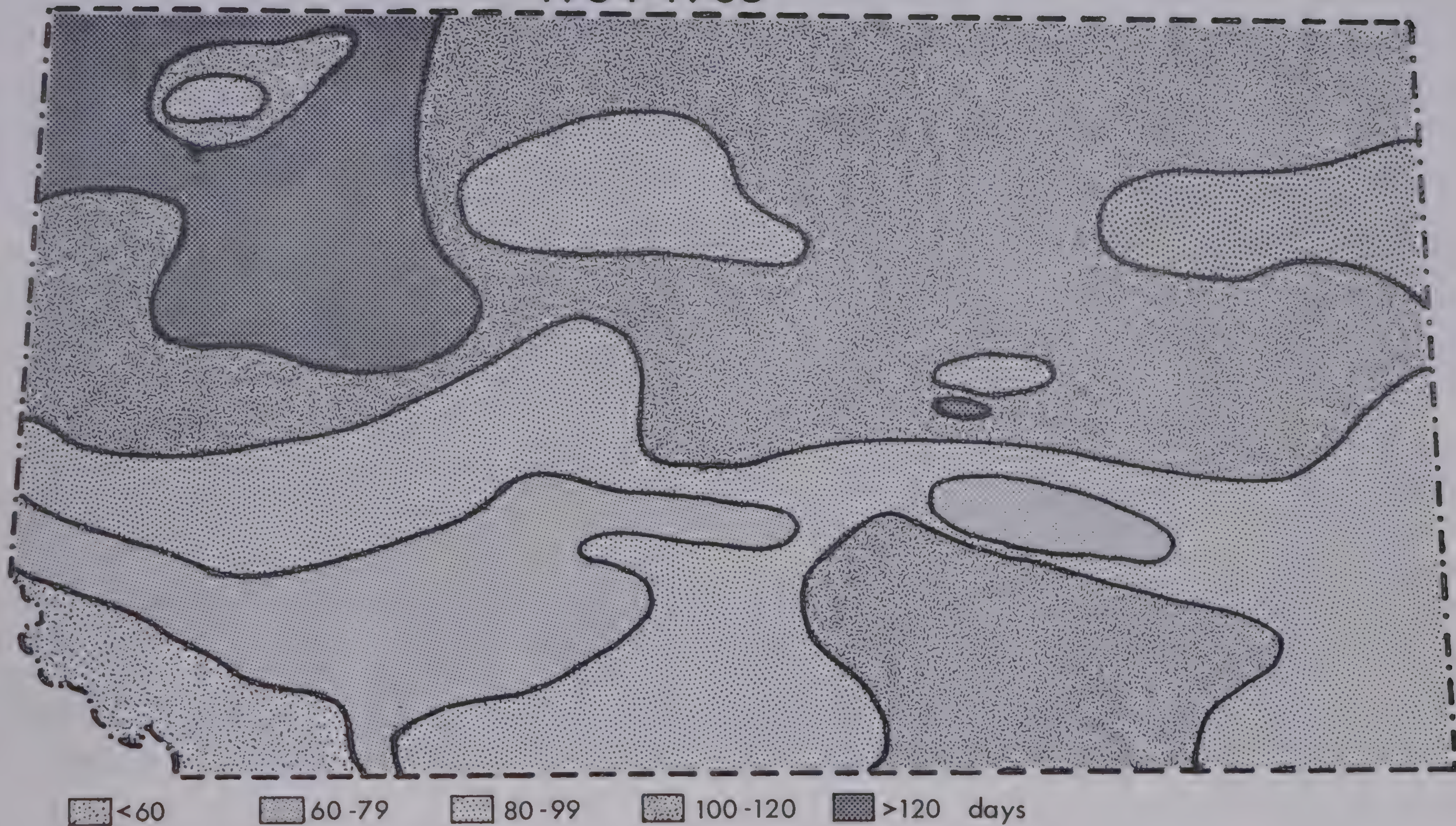


FIGURE 5.8

Table 5.3

MEAN DATES OF FROST OCCURRENCE

STATION	MEAN DATE OF LAST OCCURRENCE OF 32°F IN THE SPRING	MEAN DATE OF FIRST OCCURRENCE OF 32°F IN THE FALL
Athabasca	June 11	September 2
Athabasca 2	May 28	September 14
Bald Mtn.	May 17	September 14
Beaverlodge	May 24	September 11
Calmar	May 26	September 11
Campsie	June 18	August 30
Cold Lake	May 24	August 30
Conklin Lo.	June 6	September 12
Deer Mtn.	May 27	September 13
Doucette	May 28	September 14
Economy	May 15	September 18
Edson	June 18	August 28
Elk Point	June 2	September 7
Entrance	June 23	August 21
Fairview	May 16	September 15
Falher	May 24	September 11
Fort Saskatchewan	May 21	September 14
Goose Mtn.	June 10	August 31
Grande Prairie	May 17	September 14
Heart Lake	May 31	September 13
High Prairie	June 2	September 6
Hinton	June 26	August 24
House Mtn.	May 30	September 11
Iron River	May 25	September 6
Kakwa Lookout	May 24	September 4
Kinuso	June 8	September 9
Lac La Biche	May 31	September 12
Marten Mtn.	May 26	September 12
Meanook	May 19	September 17
Newbrook	June 11	August 26
Pelican Mtn.	May 29	September 16
Pimple	May 24	September 13
Puskwaskau	May 20	September 18
Ranfurly	May 31	September 10
Rochester	June 10	August 31

Table 5.3 continued

STATION	MEAN DATE OF LAST OCCURRENCE OF 32°F IN THE SPRING	MEAN DATE OF FIRST OCCURRENCE OF 32°F IN THE FALL
Round Hill	June 3	September 6
Rycroft	June 2	September 4
Salt Prairie	June 6	September 10
Simonette Lo.	May 29	September 6
Sion	May 25	September 16
Slave Lake	June 3	September 11
Snuff Mtn.	May 12	September 18
Swan Dive	May 29	September 10
Sweathouse	May 17	September 15
Thorsby	June 2	September 9
Vegreville	May 25	September 14
Vermilion	June 5	September 6
Wabasca	May 30	September 13
Wagner	June 4	September 12
Whitecourt	June 20	September 4
Whitecourt Lo.	June 7	September 7
Yellowhead	June 5	September 5

MEAN LENGTH OF PERIOD FROM LAST OCCURRENCE OF 28° F IN SPRING TO FIRST OCCURRENCE IN FALL
1954-1968

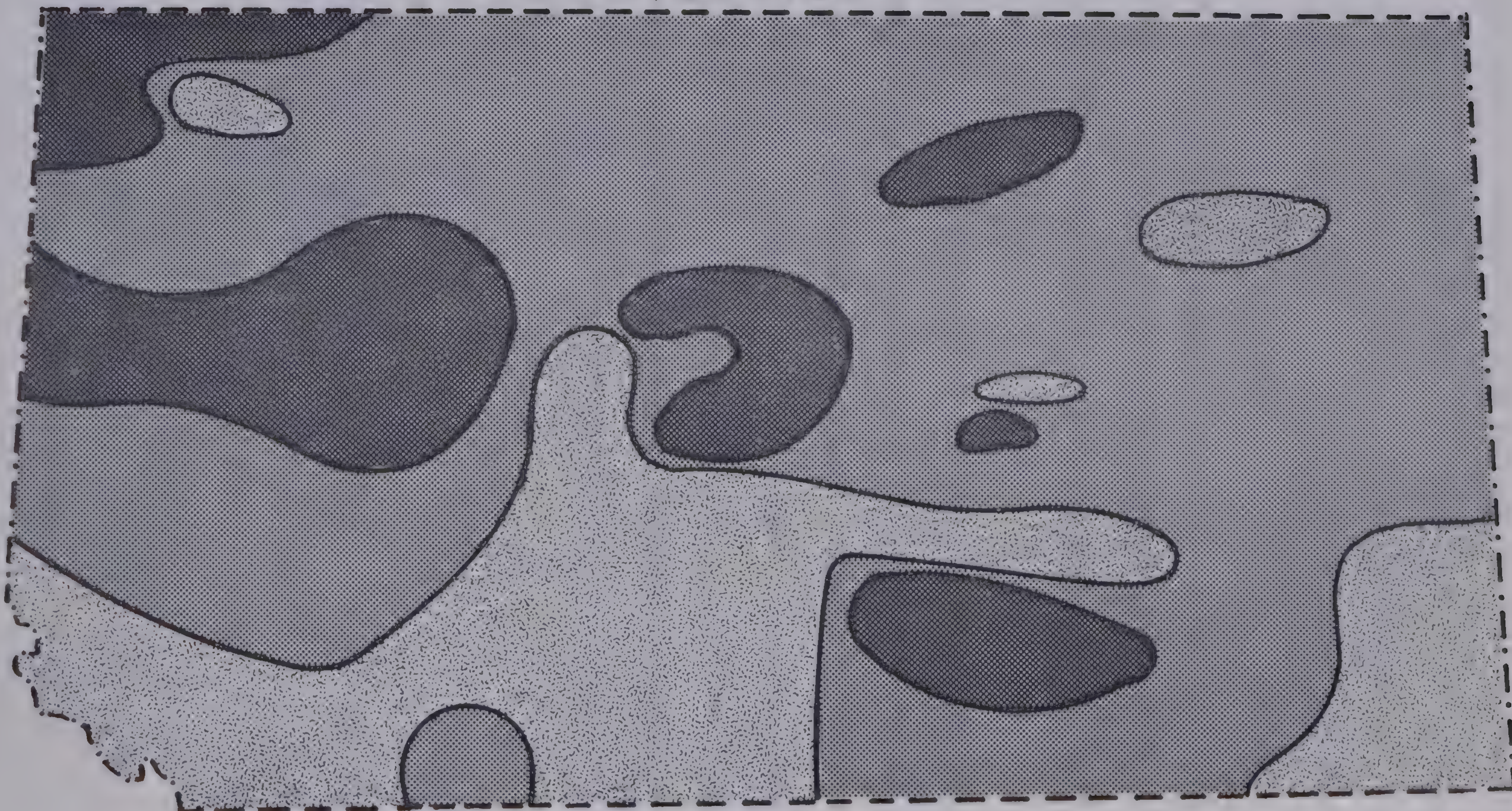


FIGURE 5.9

spring occurrence of minimum temperatures below 28°F and the first fall occurrence of minimum temperatures above 28°F. Much the same areal pattern as for frost-free days is shown, as again the northwest indicates a maximum (>140 days) and the central areas exhibit minimum killing frost-free periods (<120 days). An additional maximum is found in the southeast portion surrounding the stations Fort Saskatchewan and Sion. The minimum period found in association with Vermilion and Elk Point stations is surprising considering the southeast portion, in general, is agriculturally developed land.

The majority of the vegetational growth within the area can withstand occasional temperatures of 32°F but the occurrence of temperatures at 28°F usually results in permanent injury if not cessation of growth. Consequently, the length of killing frost-free period appears more important to vegetational association than simply the frost-free period. Consequently,the dates of the last spring occurrence and first fall occurrence of killing frosts appears in Table 5.4.

Photoperiod

The high dependence of day length upon latitude results in only small variances within the study area. The southern parallel of latitude of the study region has an average day-length of 15.1 hours, while the northern parallel represents 15.5 hours. By employing a computer program written by Reifsnyder, micro day-length differences are found between stations at relatively the same latitude. The day-length calculations are the difference between the times of sunrise and sunset, given the longitude and latitude of each station.

Table 5.4

MEAN DATE OF KILLING FROST OCCURRENCE

STATION	MEAN DATE OF LAST OCCURRENCE OF 28^{o} F IN SPRING	MEAN DATE OF FIRST OCCURRENCE OF 28^{o}F IN FALL
Athabasca	May 24	September 16
Athabasca 2	May 10	September 20
Bald Mtn.	May 3	September 26
Beaverlodge	May 8	September 19
Calmar	May 9	September 20
Campsie	May 22	September 12
Cold Lake	May 12	September 27
Conklin Lo.	May 17	September 25
Deer Mtn.	May 7	September 24
Doucette	May 10	September 22
Economy	May 3	September 27
Edson	May 23	September 14
Elk Point	May 20	September 15
Entrance	May 25	September 14
Fairview	May 4	September 26
Falher	May 10	September 20
Fort Saskatchewan	May 8	September 27
Goose Mtn.	May 25	September 15
Grande Prairie	May 5	September 21
Heart Lake	May 16	September 19
High Prairie	May 13	September 19
Hinton	May 23	September 14
House Mtn.	May 9	September 27
Iron River	May 15	September 19
Kakwa Lookout	May 9	September 19
Kinuso	May 18	September 16
Lac La Biche	May 11	September 22
Marten Mtn.	May 12	September 22
Meanook	May 6	October 1
Newbrook	May 21	September 12
Pelican Mtn.	May 13	September 30
Pimple	May 4	September 24
Puskwaskau	April 30	September 30
Ranfurly	May 16	September 26
Rochester	May 19	September 18

Table 5.4 continued

STATION	MEAN DATE OF LAST OCCURRENCE OF 28°F IN THE SPRING	MEAN DATE OF FIRST OCCURRENCE OF 28°F IN THE FALL
Round Hill	May 21	September 16
Rycroft	May 23	September 13
Salt Prairie	May 14	September 21
Simonette Lo.	May 9	September 17
Sion	May 10	September 28
Slave Lake	May 13	September 23
Snuff Mtn.	April 29	September 27
Swan Dive	May 2	September 23
Sweathouse	May 1	September 29
Thorsby	May 14	September 24
Vegreville	May 13	September 28
Vermilion	May 21	September 18
Wabasca	May 14	September 23
Wagner	May 16	September 25
Whitecourt	May 30	September 13
Whitecourt Lo.	May 21	September 13
Yellowhead	May 18	September 19

Likewise, the values for the solar energy at the top of the atmosphere ($Q_{\circ}$), illustrates the same latitudinal dependence. The solar energy increases with decreasing latitude. Typical variability of $Q_{\circ}$ is illustrated in Table 5.5 for selected stations in the study area.

Table 5.5

Solar Energy at the Top of the Atmosphere in Langleys/ day

Station	May 1	June 1	July 1	Aug. 1	Sept. 1
Beaverlodge	818.3	961.7	980.1	869.1	668.9
Swan Dive	821.4	962.7	980.8	871.5	673.5
Whitecourt	825.2	964.0	981.7	874.3	679.3
Vegreville	829.4	965.3	982.6	877.5	685.7
Thorsby	831.0	965.9	982.9	878.7	688.0

(after Reifsnyder, 1970)

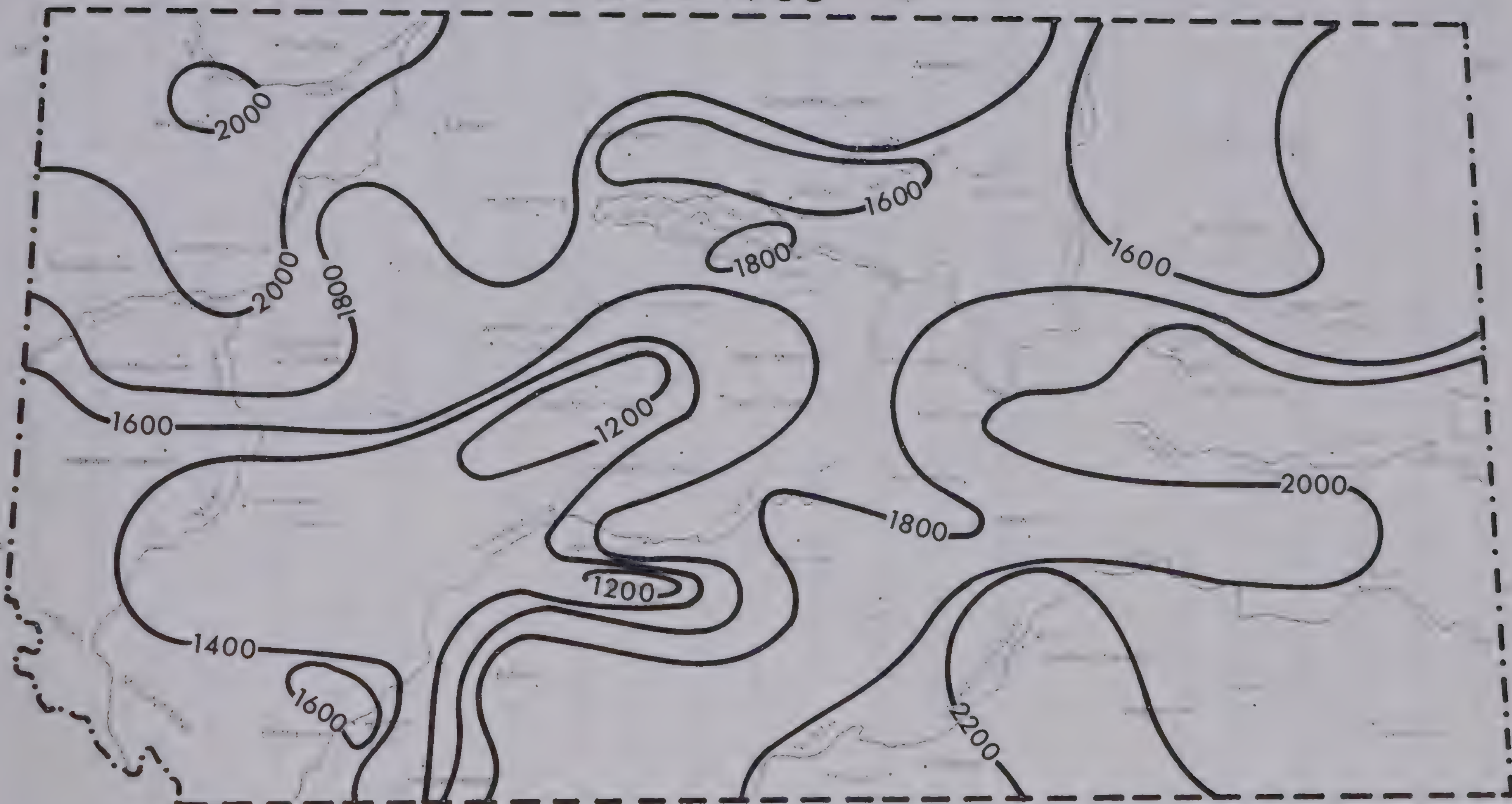
The above empirical estimation technique was, therefore, able to provide mean monthly day length values to be used in the later statistical analysis.

Degree-Days

As frost-free days indicate the length of the growing season, so also the accumulation of degrees above various base temperature levels serves to indicate the amount of potential heat available. Degree-days for May to September were calculated above the mean temperatures of 28°F, 32°F and 42°F.

The degree-days above 42°F, as shown in Figure 5.10,

DEGREE-DAYS ABOVE 42° F
1954-1968



VALUES IN DEGREES FAHRENHEIT

FIGURE 5.10

MAY-SEPTEMBER

demonstrate relative maximums (>2000) in the southeast and northwest portions of the study area. Similar to the mean temperature distribution, the minimum areas (<1200) are found in association with Goose Mountain and Whitecourt Lookout. Similar patterns are also exhibited in the degree-days above 32°F and 28°F. These relative magnitudes of the influence of temperature for vegetational growth, consequently, become yet another input parameter to the later statistical analysis.

Mean Frequency of Days above Various Base Temperatures

Frost-free periods provide a measure of the length of the summer period without frost. Calculated from the last occurrence of frost in the spring to the first occurrence in the fall, the frost-free period, in some cases, does not accurately represent the growing period. Does the occurrence of one night of frost in July indicate that the growth period of that year begins after July? In order to eliminate this type of error in growing season estimates, the mean frequency of the number of days per month above 28°F, 32°F and 42°F minimum temperatures was calculated.

Generally, for the mean frequency above 28°F, the study area exhibits only minor fluctuations of 1 to 3 days among stations. The relative minimum appears at Whitecourt Lookout as 28 days. However, more complex patterns become apparent in the mean frequency of days above 32°F. Minima appear at Whitecourt Lookout, Hinton and Entrance. As noted previously, the micro-climatic variations within the river valley account for these lower values in minimum temperatures.

More striking variations in the mean frequency of days above

42°F is shown in Figure 5.11. Distinct minimums (<12 days) are noted in the southwest of the study area and at the Athabasca station. Each of these stations - Hinton, Entrance and Athabasca - is found in the Athabasca River Valley. Relative maximum values are again found in the southeastern and the northwestern portions of the study area.

Conclusions

The majority of the variables shown above are inputs for statistical analysis, in later chapters, but in the form of mean monthly, rather than seasonal values. This chapter, therefore, completes one secondary objective of this study - to provide a climatological base to the study region.

MEAN FREQUENCY OF THE DAYS PER MONTH ABOVE 42° F 1954-1968

VALUES IN DAYS

MAY-SEPTEMBER

FIGURE 5.11

Chapter 6

Evapotranspiration and Water-Balance

Planning and design of programs for managing plant crops are dependent to a large degree upon the available soil moisture. This requires some form of estimation of evaporation loss to the atmosphere. The subsequent balance between precipitation and evaporation-transpiration determines the need for irrigation requirements. In order to provide an approximate evaluation of the vegetational moisture requirements within the study area, empirical estimation of evapotranspiration and water deficiency per station, was, therefore, studied.

Numerous techniques for the calculation of potential evapotranspiration, evaporation, and actual evapotranspiration appear in the literature of many disciplines. Potential evapotranspiration is the

> "maximum quantity of water capable of being lost, as water vapour, in a given climate, by a continuous stretch of vegetation covering the whole ground when the soil is kept saturated. Evaporation is the emission of water vapour by a wet or a free surface of water, in liquid or solid state, at a temperature below boiling point. Actual Evapotranspiration is the sum of the quantities of water vapour evaporated by the soil and transpired by plants under existing meteorological and soil moisture conditions." (W.M.O., 1966, p.1).

The techniques of Thornthwaite (1948, 1955), Blaney and Criddle (1950), Penman (1948), Turc (1954), Holderidge (1947) and Baier and Russelo (1968), each provides empirical formulae based upon a variety of meteorological input parameters.

Keeping in mind the nature of the available input data--temperature and precipitation--the above techniques therefore essentially become a comparison between Thornthwaite and Holderidge. The aerodynamic approach as outlined by Baier and Russelo, estimates latent

evaporation dependent upon wind, solar radiation at the top of the atmosphere, maximum temperature and vapour pressure deficit. Since this method is able to account for 70 to 86 per cent of the variation in comparison with atmometers and pans, the results of this method will be utilized as a "yardstick" when comparing the above two methods. Because of the complexity of the input parameters for the Baier and Russelo equation, it was only of use at the first-order meteorological stations. Consequently, in order to choose the evaporation estimation technique which applied to all study area stations, the relevant techniques were applied to the Beaverlodge data.

Holderidge

As defined by Holderidge, "potential evapotranspiration is a hypothetical figure against which other moisture values can be compared." (Holderidge, 1962, p. 4). His results are based upon the input variables--temperature and precipitation.

As with most evapotranspiration techniques, a general formula is outlined:

$$PE = 58.93 \times \frac{\text{Unit period of time}}{\text{No. of units of time}} \times \begin{array}{c}\text{Comparative plant growth}\\ \text{mean temperature } ^{o}\text{C.}\end{array}$$

where the unit period of time is usually taken as one year, the number of units of time, therefore is either 365 or 366 days and the comparative plant growth mean temperature is the mean annual biotemperature, as defined in Chapter 2. It would appear, from analysis of the formula, that the failure to include a correction factor for the variability of incoming radiation as a function of latitude and the use of an empirical constant, 58.93, places excessive weighting on the

comparative plant growth mean temperature.

Comparison of the evaporation estimates by Thornthwaite and Holderidge, utilizing Baier and Russelo as the "yardstick" will be outlined later.

Thornthwaite

Owing to the complexity and difficulty in performing the actual measurement of the interaction among soil moisture, soil structure and climate, the simulation of these intercorrelations through the use of empirical formulae becomes necessary.

Thornthwaite, in 1948, presented a formula to calculate potential evapotranspiration at a point, which is given by:

$$PE = 1.6\left(\frac{10T}{TE}\right)^a \qquad (1)$$

where potential evapotranspiration (PE) is the monthly unadjusted PE in centimeters, T is the mean monthly temperature (^oC), TE is the annual temperature-efficiency index (^oC) and a is the cubic function of TE.

The temperature-efficiency (i) per month can be better expressed mathematically as:

$$i = \left(\frac{t_i}{5}\right)^{1.514} \qquad (2)$$

where t_i is the mean monthly temperature of month i. The annual temperature-efficiency index (TE) then is expressed by:

$$TE = \sum_{n=1}^{12} i_n$$

where n is the month of the year.

Similarly, a can also be expressed as:

$$a = 6.75 \times 10^{-7}(TE)^3 - 7.71 \times 10^{-5}(TE)^2 + 1.79 \times 10^{-2}TE + 0.492$$

where TE is the same as mentioned above.

Shortcomings or weaknesses within the Thornthwaite method are aptly illustrated in the literature. These weaknesses are: one, the lag of mean air temperature compared with direct solar radiation; two, the assumption that evapotranspiration ceases once the mean air temperature falls below 0^{o}C.; third, the lack of incorporating a correction for wind speed; fourth, exclusion of the influence of warm and cold air advection on temperature; and fifth, the assumption that temperature is an adequate indicator of the energy needed in evaporation measurements. Additional shortcomings become apparent when soil moisture levels are utilized in the bookkeeping method for water-balance studies. However, despite the exclusion of radiation and wind, this empirical method of calculating potential evapotranspiration as a function of mean air temperature has gained wide acceptance in agriculture, forestry, and hydrology because of its relative simplicity to provide comparative indices for areally different stations.

An extremely dense network of climatological stations exists in the study area, but, as mentioned previously, the majority of these are Alberta Forestry Towers, reporting, at most, on a 7-month basis. Consequently, the above mentioned Thornthwaite formulae were adjusted from the 12-month to the 7-month time period to conform with the length of tower reporting periods.

However, both temperature and precipitation for the winter months are missing, thereby, invalidating the present use of the 12-month evaporation formulaes. Thornthwaite's formula offers the best

opportunity for modification to yield reliable results.

Modification of the Thornthwaite technique, by employing two assumptions provided the needed technique for evapotranspiration estimation. Assumption one is that within the study area, the mean temperatures for the months November to March, inclusive, are below 32°F. This results from the basic premise of the Thornthwaite formula which postulates that potential evapotranspiration is zero if the mean monthly temperature is below 0°C.

Data from stations with long-term records indicate that the above assumption appears to be valid (Table 6.1).

Table 6.1

1931-1960

MEAN MONTHLY TEMPERATURE (°F) AT SELECTED STATIONS

	JAN.	FEB.	MAR.	...	NOV.	DEC.
Athabasca	1.5	6.2	17.9	...	21.4	7.6
Beaverlodge	7.4	12.1	21.6	...	23.7	12.8
Calmar	5.7	10.4	20.7	...	23.9	12.6
Cold Lake	-2.1	7.5	18.0	...	21.9	11.8
Edson	8.4	13.8	23.6	...	23.5	12.5
Fairview	2.4	7.7	19.6	...	20.3	8.6
Ranfurly	2.9	7.5	18.9	...	22.0	10.1
Wagner	3.1	8.6	19.4	...	23.3	9.6

(after Climatic Normals, Vol. 1.)

To ensure correctness of the assumption, not only for long-term

averages but also for individual years, comparison at Beaverlodge for the years 1954-1956 is shown below (Table 6.2).

Table 6.2

POTENTIAL EVAPOTRANSPIRATION 1954-1968 FOR BEAVERLODGE (after Thornthwaite)

YEAR	MONTH	12-MONTH POTENTIAL EVAPOTRANSPIRATION INCHES	7-MONTH POTENTIAL EVAPOTRANSPIRATION INCHES	RESIDUALS
1954	4	0.4	0.0	0.4
	5	2.7	2.9	-0.2
	6	3.6	3.8	-0.2
	7	4.4	4.5	-0.1
	8	3.8	3.9	-0.1
	9	2.2	2.4	-0.2
	10	1.1	1.1	0.0
1955	4	1.0	0.9	+0.1
	5	2.4	2.5	-0.1
	6	4.2	4.3	-0.1
	7	4.6	4.7	-0.1
	8	3.8	3.9	-0.1
	9	2.2	2.3	-0.1
	10	0.9	0.8	+0.1
1956	4	1.0	0.8	0.2
	5	3.5	3.5	0.0
	6	3.7	3.8	-0.1
	7	4.8	4.6	+0.2
	8	4.2	4.2	0.0
	9	2.1	2.3	-0.1
	10	0.8	0.4	+0.4

The difference between the findings based upon 12 months and 7 months data is a result of the earlier discrepancies in mean monthly calculation.

Two methods are now available for the calculation of Potential Evapotranspiration--Thornthwaite and Holderidge. The unit period of time, as noted in the formula by Holderidge, can be reduced to a monthly basis such that 7-month estimates of potential evapotranspira-

tion are quite feasible. But which is the better one?

In order to answer the above question, yearly totals of potential evapotranspiration for the years 1954-1956 are presented in Table 6.3. Keeping in mind that the Baier and Russelo value of 18.5 inches is the "yardstick", the Thornthwaite long-term total of 19.6 inches appears to be the better estimation formula. The deviation of 5 per cent for Thornthwaite and 17 per cent for Holderidge from Baier and Russelo's estimate thereby furnishes the answer to the above question. Consequently, in subsequent calculations of potential evapotranspiration, the 7-month Thornthwaite procedure will be followed.

Potential evapotranspiration (PE) was then calculated for each of the five study area stations with the results for the months May to September becoming data for later statistical analysis. Figure 6.1 illustrates the variability for the seasonal average (May-September) at each station from 1954 to 1968. Areas of relatively low PE (16.0") are found in the Swan Hills in association particularly with the Goose Mountain Lookout station. Conversely, two areas of maximum PE (18.0") are noted in the southeast and northwest portions of the study area. These two areas correlate with the lower agricultural land whereas the Swan Hills are characteristic of the forested and upland regions.

The second assumption is that the winter precipitation within the study area is able to recharge soil moisture storage successfully by March 30th, each year, to the 4.00-inch level. Four inches is the base level assumed for the purpose of this thesis. Again cross-checking with the above mentioned stations ensures that with the amount of water in storage at the end of October plus the November to March precipitation, ample water for four inch recharge is provided. The long-term

Table 6.3

Comparative Analyses after Holderidge and Thornthwaite

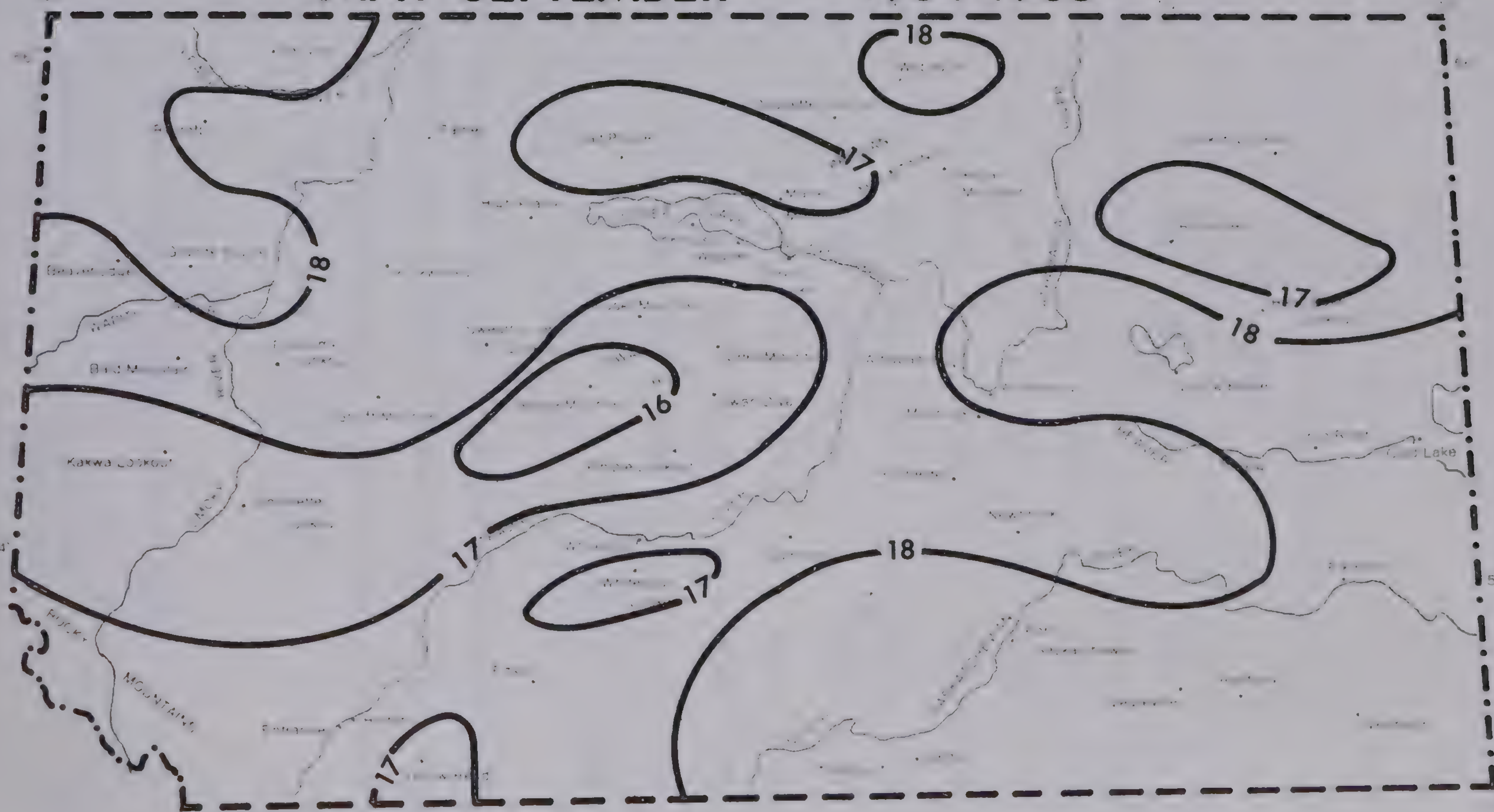
BEAVERLODGE

1954 - 1965

YEARS	MEAN ANNUAL TEMPERATURE (°C)	MEAN ANNUAL BIOTEMP (°C)	TOTAL ANNUAL PRECIP. (IN.)	HOLDERIDGE PE (IN.)	THORNTHWAITE PE (IN.)
1954	1.06	6.2	18.6	14.3	18.6
1955	0.32	6.1	17.2	14.3	19.4
1956	1.61	6.7	17.3	15.6	19.5
1957	1.95	6.3	23.7	14.6	19.2
1958	2.84	7.0	14.5	16.3	20.9
1959	1.52	6.0	15.6	13.9	18.8
1960	2.63	6.6	19.4	15.2	20.1
1961	1.97	6.8	16.4	15.8	19.9
1962	1.98	6.5	19.1	15.2	20.1
1963	2.26	6.9	14.3	16.0	20.1
1964	1.11	5.9	28.8	13.8	19.2
1965	0.86	6.3	25.4	14.5	19.4
MEAN	1.68	6.4	19.2	15.0	19.6

AGROMETEOROLOGY (BAIER AND RUSSELO, 1968) PE LONG TERM NORMAL 18.5 IN.

POTENTIAL EVAPOTRANSPIRATION
MAY-SEPTEMBER 1954-1968



VALUES IN INCHES

FIGURE 6.1

averages of precipitation for the same stations as before are shown in Table 6.4.

Table 6.4

LONG-TERM NORMALS OF PRECIPITATION (IN.)

1931 - 1960

STATION	JAN.	FEB.	MAR.	...	NOV.	DEC.	TOTAL
Athabasca	1.17	.97	.85	...	1.03	1.13	5.2
Beaverlodge	1.26	1.16	1.01	...	1.29	1.15	5.9
Calmar	0.84	0.67	0.83	...	0.92	0.82	4.1
Cold Lake	0.99	0.71	1.03	...	1.00	1.09	4.8
Edson	1.00	0.75	0.95	...	1.03	0.99	4.7
Fairview	1.23	1.19	1.03	...	1.27	1.33	6.1
Ranfurly	0.80	0.60	0.82	...	0.90	0.86	4.0
Wagner	0.87	0.92	0.59	...	1.07	1.16	4.6

(after Climatic Normals, Vol. 2)

Table 6.5 provides the water deficiency patterns on a finer scale per year for 1955 and 1956. In the calculation of the 12-month deficit values, since the soil moisture value is carried over from one year to the next, the year 1954 is not illustrated below.

Table 6.5

YEARLY WATER DEFICIENCY ABOVE 4 INCHES
BEAVERLODGE

YEAR	12-Month Water Deficiency	7-Month Water Deficiency	Residuals
1955	3.94	4.15	-.11
1956	5.20	4.99	+.21

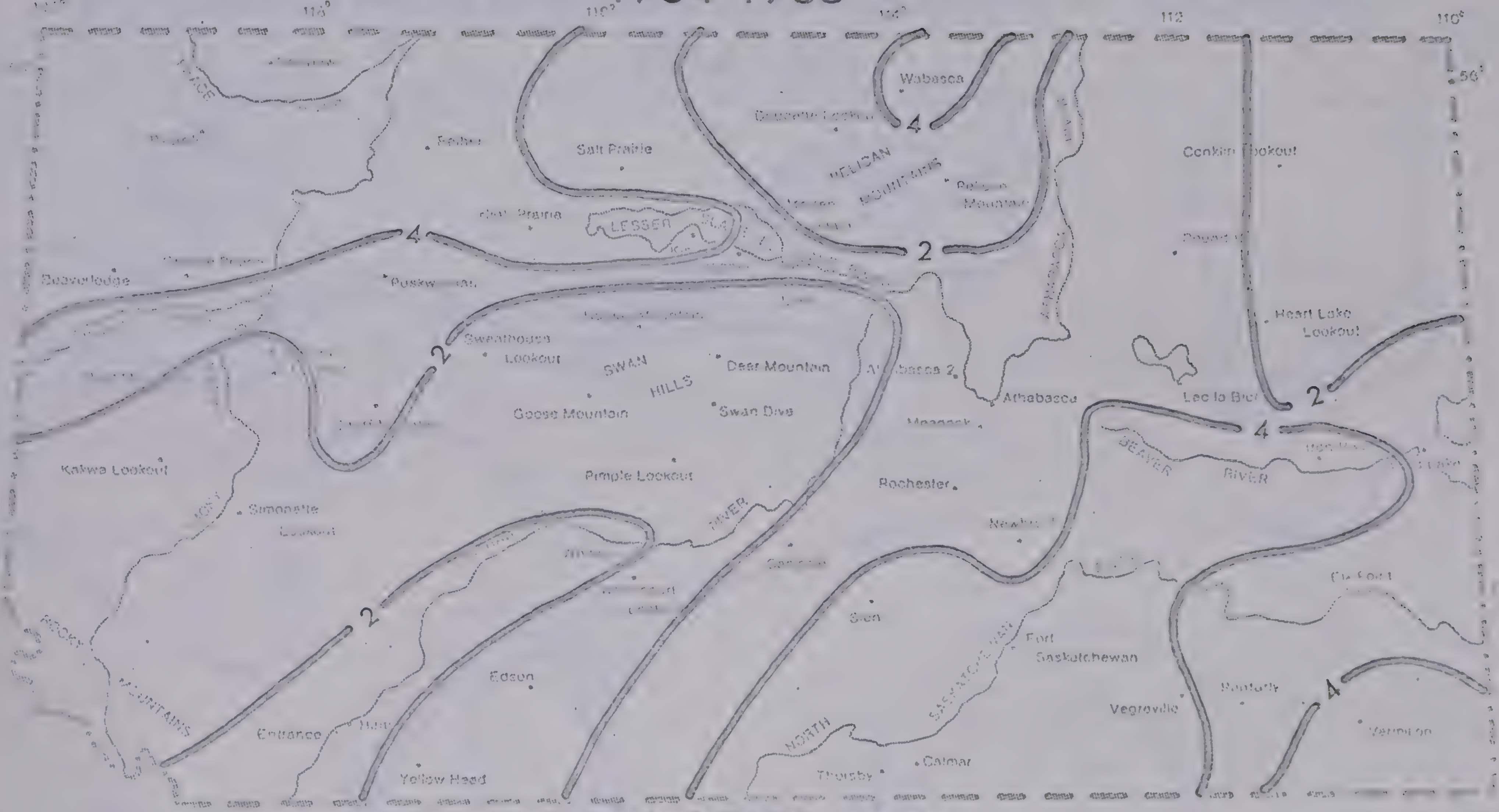
As before, the change to the 7-month period for calculation of the Thornthwaite deficiency patterns appears to provide reasonable estimates for water deficit. The spatial variations in the deficiency per station are shown in Figure 6.2. As before, seasonal averages point out relative minima values in the Swan Hills with maximum figures noted in the southeast and northwest of the study area. In comparison with the seasonal means for potential evapotranspiration, it would appear generally that water deficit is greatest where high potential evapotranspiration is associated with the agricultural land.

Likewise, the calculation via the Thornthwaite bookkeeping procedure, provides an estimate of actual evapotranspiration. Figure 6.3 notes the macro 7-month variations within the study area. Where areas of high potential evapotranspiration occurred, for example, Fort Saskatchewan, correspondingly low actual evapotranspiration is noted, thereby creating a large water deficiency. This occurs when soil storage reaches zero such that the actual evapotranspiration is equal to the precipitation. The water deficiency then becomes the difference between precipitation and potential evapotranspiration subtracted from the previous month's storage value. An example of this point appears later in the Chapter in Table 6.6.

Water-Balance

The technique of calculating water-balance is much more complicated than the simple difference between precipitation and potential evapotranspiration. A colleague of Thornthwaite's, Mather, explained the bookkeeping method as follows:

WATER DEFICIENCY ABOVE 4″ STORAGE
1954-1968



VALUES IN INCHES

MAY-SEPTEMBER

FIGURE 6.2

ACTUAL EVAPOTRANSPIRATION ABOVE 4″ STORAGE

1954-1968

VALUES IN INCHES

MAY-SEPTEMBER

FIGURE 6.3

"When the potential evapotranspiration is compared with the precipitation, and allowance is made for the storage of water in the ground and its subsequent use, periods of moisture deficiency and excess are clearly revealed and an understanding of the relative moistness or aridity of a climate is obtained. If the amount of precipitation is always greater than the evapotranspiration, the soil will remain full of water and a water surplus will occur. On the other hand, if precipitation is always less than the potential evapotranspiration or water need, moisture will be limited and a moisture deficit will exist. Under normal conditions both of these conditions will occur during the course of a year or several years at a place so that a comparison of the potential evapotranspiration with the precipitation will show both a wet or a cold season in which water need is less than the available precipitation. Under such circumstances there usually occurs a period of full soil moisture storage when precipitation is greater than the moisture demand and a moisture surplus accumulation; a drying period, when the moisture in the soil is used by the plants, the soil moisture storage is diminished and a moisture deficit occurs; and a re-moistening season, when precipitation exceeds water use and the soil moisture storage is replenished. The values of moisture surplus and deficiency as well as of the other factors of the water balance can be computed by means of a simple water balance bookkeeping procedure." (Mather, 1959, p. 251)

In order to describe the complete water-balance bookkeeping procedure better, an example for Beaverlodge 1968 is shown in Table 6.6. Employing Thornthwaite's original formulae, as presented in equation (2), the heat unit I is the summation of the monthly temperature-efficiency (i) value. By substituting this into equation (1), the unadjusted potential evapotranspiration in centimeters is shown. By applying a correction factor for the specific latitude, the adjusted PE (in centimeters as well as in inches) is then calculated. The next step in the procedure after introducing monthly totals of precipitation is calculating the value for soil moisture storage change. If precipitation is less than PE the storage change becomes negative, as noted for April. Assuming a storage level of four inches in March, the addition of March storage and April storage change yields the storage for April. When the potential storage loss is greater than the storage, the soil moisture drops to zero. It remains at zero until the storage

TABLE 6.6

POTENTIAL EVAPOTRANSPIRATION CALCULATIONS FOR THE YEAR [illegible]

BEAVERLODGE

MONTH	APR	MAY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	11.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PRECIPITATION	0.70	1.20	3.50	0.80	2.10	1.40	[illegible]	12.50
STOR. CHANGE	-0.24	-0.04	-0.2[illegible]	-3.78	0.0	0.0	0.0	
STORAGE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ACT. EVAPOTRANS.	0.94	2.34	3.78	3.54	2.10	1.60	0.20	17.58
DEFICIENCY	0.0	0.0	0.0	1.24	0.0	0.75	0.02	2.51
SURPLUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RUNOFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[illegible]	[illegible]							

[illegible]

change becomes positive and moisture is available to replenish the soil. There can not be a negative storage level. The subsequent values of actual evapotranspiration, deficit, surplus, and runoff are dependent upon the interrelationships of precipitation, PE, and storage. For example, if the storage change is zero and storage is zero actual evapotranspiration is equal to the precipitation, since this is the maximum available moisture for evapotranspiration under these circumstances. The deficit then becomes the value of potential storage change (difference between precipitation and PE). These two points are illustrated for the month of September. As a check upon the accuracy of the arithmetic the total actual evapotranspiration is equal to the potential evapotranspiration minus the total deficiency per year.

Since a 7-month technique was adopted, the surplus and runoff values are therefore not accurate, necessitating their exclusion. Surplus is the amount of water above the pre-set limit of four inches. Since the months between November and April were not included, the associated yearly surplus total is misleading.

Consequently, for further statistical analysis, the monthly values of potential evapotranspiration, actual evapotranspiration and deficit per station between 1954 and 1968 provided additional input parameters for the months May to September, inclusive.

Chapter 7

Thermo-Dew-Point Recording

Of special interest to many people--especially farmers--are the climatic variations, notably termperature and humidity, in their immediate area. The Department of Transport Weather Stations often fail to furnish accurate interpolations of the present climate, thus necessitating a different method of recording--namely mobile traversing. For example, between the stations Whitecourt and Wagner, the Swan Hills rise to a height of 2000 feet above the surrounding plains. Interpolation of thermal variability between Wagner and Whitecourt to cover the Swan Hills is therefore by no means representative.

To date quite extensive studies have been undertaken with mobile recorders but mainly in urban environs--studies concerning urban heat island effects from 1936. Use of this technique is particularly lacking in rural areas. MacPhail's (1966) description of numerous traverses in Southern Ontario and Longley and Louis-Byne's (1967) investigations of frost hollows in Alberta constitute the major work in country settings.

The technique of mobile thermo dew-point recording serves two purposes--first, the investigation of temperature variations under forest cover; and secondly, the investigation of the reliability of climate-station data as indicative of its locale. An additional use, smoothing of macroclimatic areal boundaries, dependent upon the test area cases as examples, becomes important in Chapter 9.

Theory of Operation

The thermo dew-point instrument uses a platinum resistance bulb as a humidity sensitivity cell. The air temperature recording simply functions on the basis of an electrical resistance in the metals as they undergo a temperature change. The thermo dew-point recorder is calibrated in units of temperature not in units of resistance. However, the dew-point sensor is slightly more complicated. Moisture determination is based on the fact that for any water-vapour pressure about a saturated salt solution there is an equilibrium temperature. The term "dew-point" is applied to this equilibrium temperature of the solution, being the same as the dew-point of the air. Theoretically, this is the method the Dewcel probe utilized in indicating dew-point. The probe, consisting of two parallel electrical conductors with an A.C. potential between them, is wound about a tube of wicking containing an excess of lithium chloride crystals. As a result, any decrease in the water-vapour pressure causes the solution to dry out, decreasing the flow of electricity such that the element cools to a new moisture equilibrium. Consequently, the Dewcel cannot record below 11 per cent relative humidity at high temperatures (100 - 120°F) or below 30 per cent relative humidity at very low temperatures (-40°F). Since these extremes of temperatures and humidities are rare under forest covers, it appears that for all practical purposes, the thermo-dewcel recorder functions extremely accurately for studies of this nature.

To ensure mobility, a portable battery supply with an output of 117 V. A.C. 60 cycles with an operating life of 4 hours before recharging, was essential to the instrument. Another alteration

concerned the design of a suitable protection for the thermistors attached to the front of the vehicle. As is seen in Figure 7.1, a cylinder with open ends ensured a free ventilation of the probes thus eliminating any possible warming effects.

The principle of measurement in this instrument is a wheatstone bridge circuit, as illustrated in Figure 7.2. As was mentioned previously, any change in temperature results in a change in the electrical resistance but is displayed in units of temperature. Referring to Figure 7.2, by adjusting the brush C until no current flows through the Galvanometer G, the resistance between A and C is represented by r, and between A and B by R_s, such that the following equation results:

$$R_x = \frac{R_3 + r}{R_2 + R_s - r} \times R_1$$

In the equation, R_1, R_2, R_3 are fixed resistance values so that the value R_x varies with r, making possible the direct graduation of scales on r.

Basically, this is the theory of operation, but in practice an intricate system of amplifiers, D.C. to A.C. converters, and balancing motors is used before the ambient and dew-point temperatures are recorded on the chart.

The time lag was determined for a similar instrument by Djurfors, in 1969; "the thermometer will register 63 per cent or 1/e of a sudden temperature change in .7 sec." (Djurfors, 1969, p.15.) As an example of the effiency of the thermometer, Djurfors presents the case whereby a temperature change of 1°C. with 90 per cent ex-

Figure 7.1

Mounted Foxboro Thermo Dew-Point Recorder

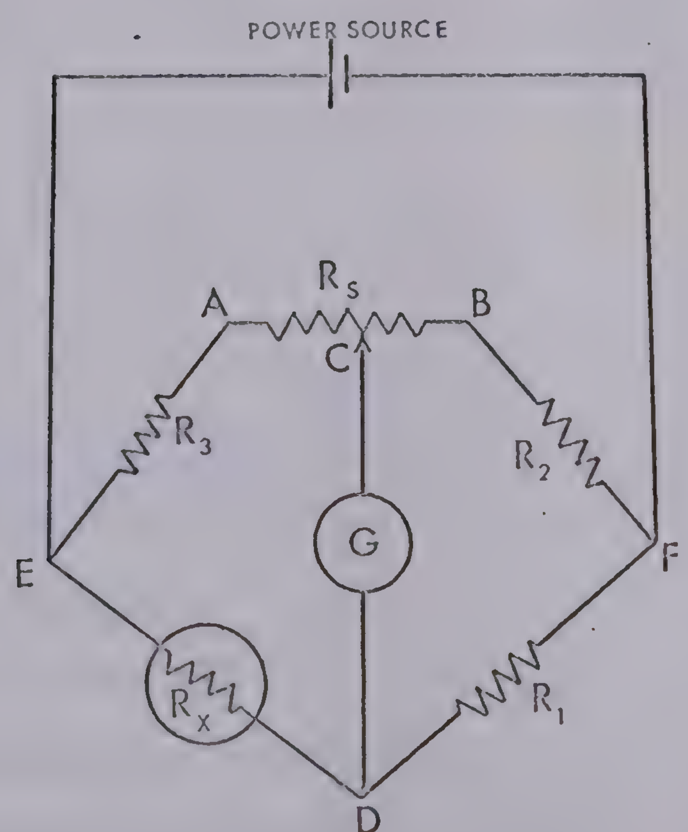


Figure 7.2

Wheatstone Bridge Circuit

plained temperature change was recorded in "1.61 sec." Moreover, considering that the vehicle is travelling at 30 m.p.h., the distance discrepancy between the place of actual temperature and the place of recording the temperature was 72 feet.

The speed of the vehicle is yet another definite factor that must be considered. It has been found from these and subsequent traverses that if the speed of the vehicle is in the range 0 - 15 m.p.h. engine heat affects the results, especially the dew-point readings. An example of such an increase is shown in Figure 7.3.

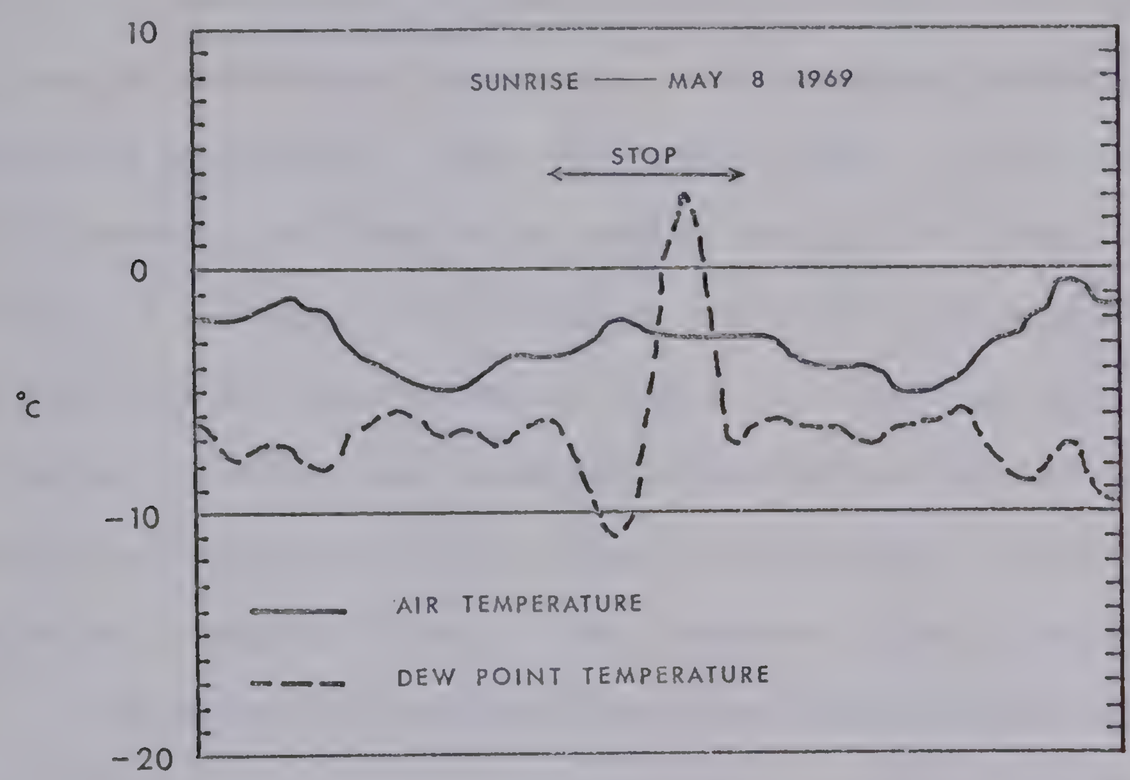


Figure 7.3
Typical reaction in the thermo dew-point traces when the vehicle is stopped--duration 2 minutes.

The dry-bulb temperature readings fail to show the same noticeable variations, but minor increases of approximately 1^{o}C have been recorded when the vehicle stops. Furthermore, at speeds above 40 m.p.h. the instrument fails to record the small cold or hot pockets which are quite noticeable at speeds of the order of 30 m.p.h. It is therefore imperative that a near constant speed be maintained during the traverse if the reference time checks at stations are to be

correlated with the constant speed recordings of the instrument.

Time of Traverses

To date the traverses have been taken at 3 distinct times of the day--sunrise, maximum heating and sunset.

Sunrise has been found to yield the greatest variations in both temperature and dew-point traces. Examples of this trend are illustrated in Figure 7.4 for Spring Creek Basin. For approximately one hour before sunrise to a half-hour after sunrise, the temperature is close to the minimum temperature. An additional half-hour of traversing is available under the forested areas, a result of the delay in the penetration of the solar heating through the forest canopy. As Figure 7.4 illustrates, a definite correlation of topography with air and dew-point temperatures is noted. It is particularly important in sunrise traverses that clear (Ci allowable) mornings be used, eliminating any cloud influences on minimum temperatures. Low cloud usually indicates a warming influence, thus invalidating the climatic trend.

The traces at the time of maximum temperature are equally time-spaced about maximum heating each afternoon--again a duration of approximately one and one-half hours. Fortunately, in the Spring Creek Basin the thermograph in the fixed Stevenson Screen indicated that the maximum heating occurred at the same general time each day--2:45 P.M. As one would expect, a large spread between the ambient and dew-point temperatures occurs, indicating a low relative humidity (Figure 7.5). Correlations of the temperature with topography are not as definite as the sunrise traverses. Attempts, again, should be made to traverse on relatively cloudless afternoons as cloud shadows produce variations

SPRING CREEK BASIN - SUNRISE TRAVERSES

MAY 7,8,9 1969

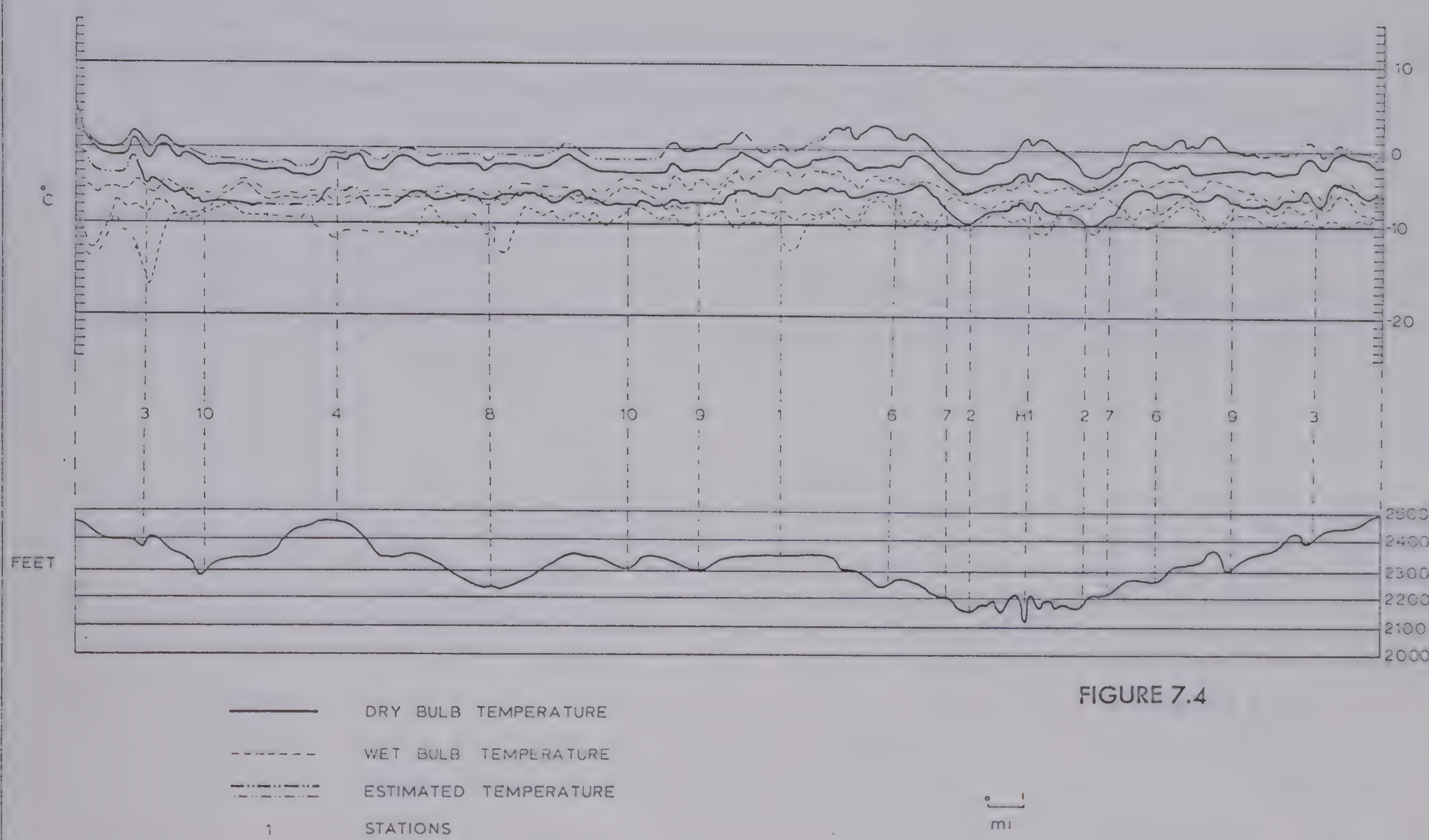
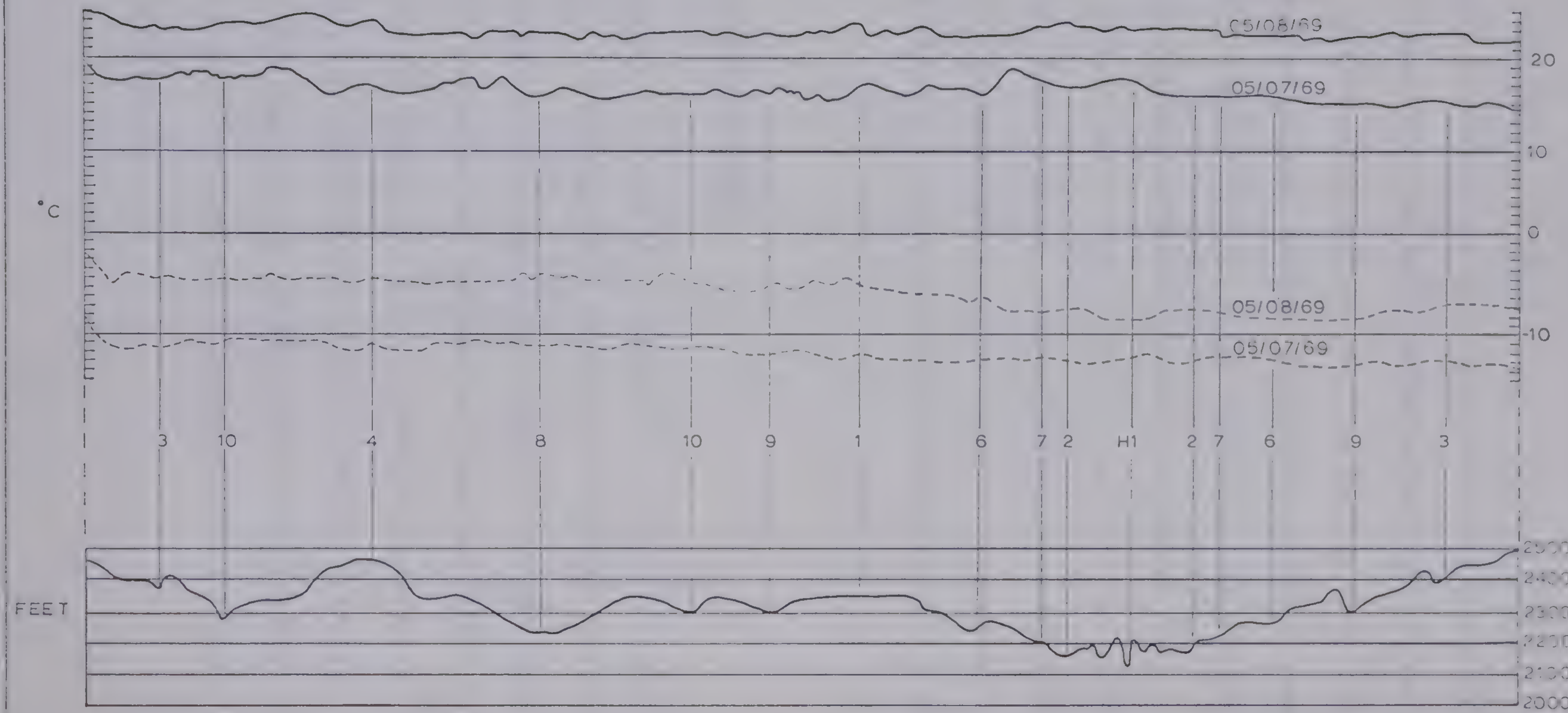


FIGURE 7.4

Vertical scale 1"= 800 ft.

SPRING CREEK BASIN - MAXIMUM HEATING

MAY 7, 8 1969



DRY BULB TEMPERATURE

WET BULB TEMPERATURE

ESTIMATED TEMPERATURE

1 STATIONS

FIGURE 7.5

0 1
mi

Vertical scale 1" = 800 ft.

on the traces. On such cloudless afternoons, the maximum temperature fluctuates vary little (1 - 2°C) in the hour and half of traversing.

Sunset traverses are also equi-spaced about the time of sunset, thus being a useful aid in establishing the rate of increasing relative humidity in the forested regions once the sun has set. As illustrated in the subsequent records (Figure 7.6), the spacing between ambient and dew-point traces decreased quite rapidly as the radiational heating diminished after the return through station 10.

At present, each traverse route was travelled, weather permitting, four times--sunrise, maximum heating, sunset, and the following sunrise. Consequently, isotherm maps and topoclimatic graphs display the resulting temperature and humidity trends in the study areas.

Testing of the Instrument

In order to check the reliability of the instrument readings in the field, two methods were followed. Firstly, cross-checking of the traces with the base reporting station while the vehicle is stopped and in motion indicated air temperature readings within ±.4°C. Readings within ±.5°C were found for the dew-point sensors by cross-checking with the wet-bulb thermometers in the Stevenson Screens. As an illustration, the observations at Swan Dive Lookout Tower for June 14 in comparison with the instrument observations at minimum temperature are shown in Table 7.1.

SPRING CREEK BASIN - SUNSET TRAVERSES

MAY 7, 8 1969

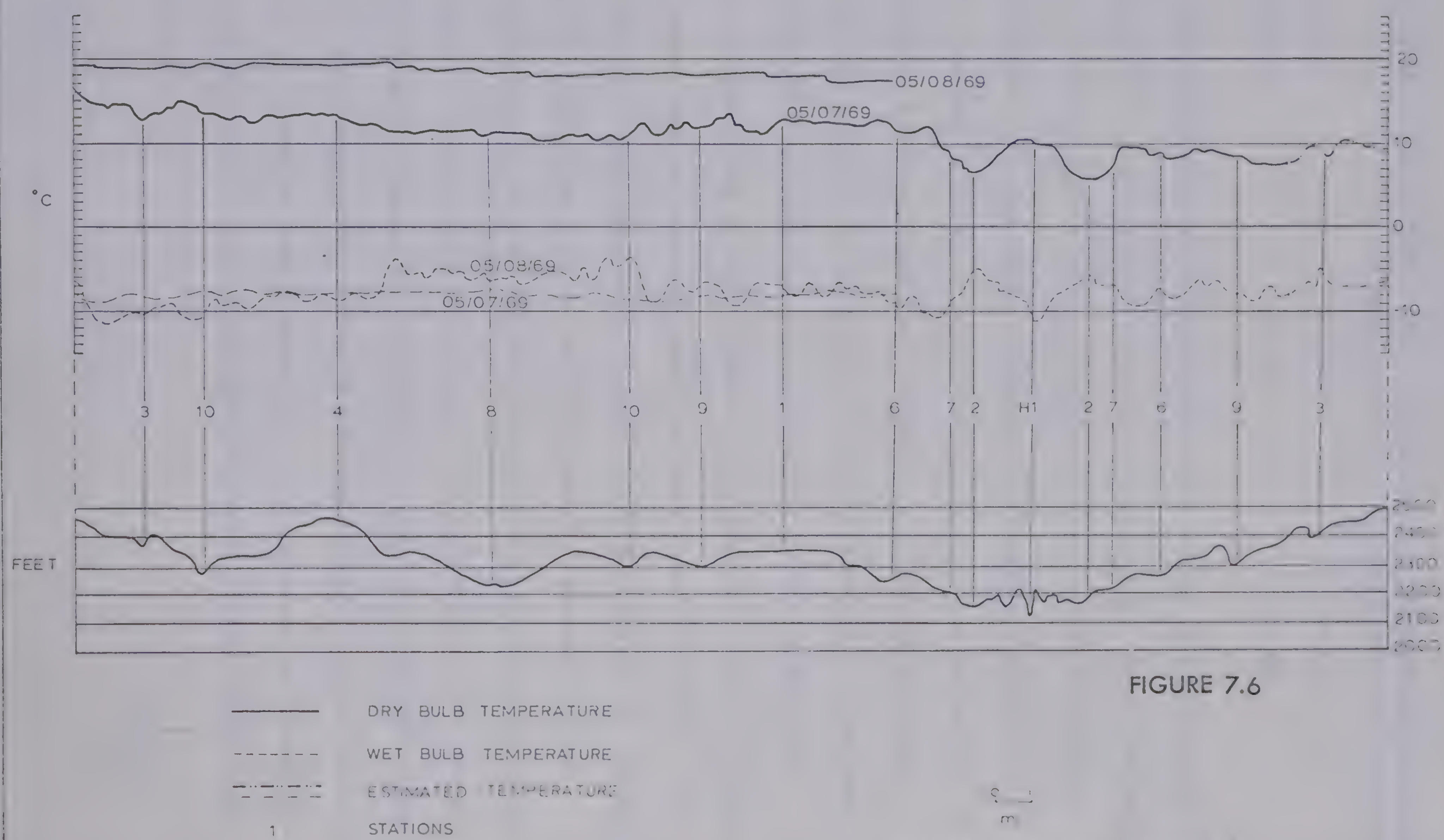


FIGURE 7.6

Vertical Scale 1" = 800 ft.

Table 7.1

Comparisons of Swan Dive Tower Observations and the Thermo-Dew-PointRecorder

	Swan Dive Tower	Thermo Dew-Point Recorder
Air Temperature	48.2°F	48.0°F
Relative Humidity	38.5%	39.0%

Secondly,repeated traverses of the same route on clear calm days indicated the constancy of the thermal variations. As illustrated in Figure 7.4, increases in ambient temperature are shown in association with station 1 on the three consecutive traverse mornings--May 7, 8 and 9th. Similarly, decreases in temperature are also noted in conjunction with reference station 2, again for all three mornings.

Also, the duplication of the same route within 10 - 15 minutes showed the validity of sampling the temperature of the stable air masses--not "freak" warm or cold spots. N. C. MacPhail noted in Figure 11 of his paper that by returning over the same route within 10 - 15 minutes, any cold spots previously recorded were eliminated by the disturbance of the air strata as the vehicle passed. However, after extensive traverses in the Spring Creek Basin and elsewhere, the author has been unable to substantiate this fact. As illustrated in Figure 7.7, identical return traces were recorded through the reference points H1, 2 and 7--this being within 10 - 15 minutes of the original traverse. As a result, the traverse would appear to be as accurate in recording one-way as on the return route--the vehicle having little effect upon the observations.

Areas of Study

To serve as indicators of the thermal variations on a macro-

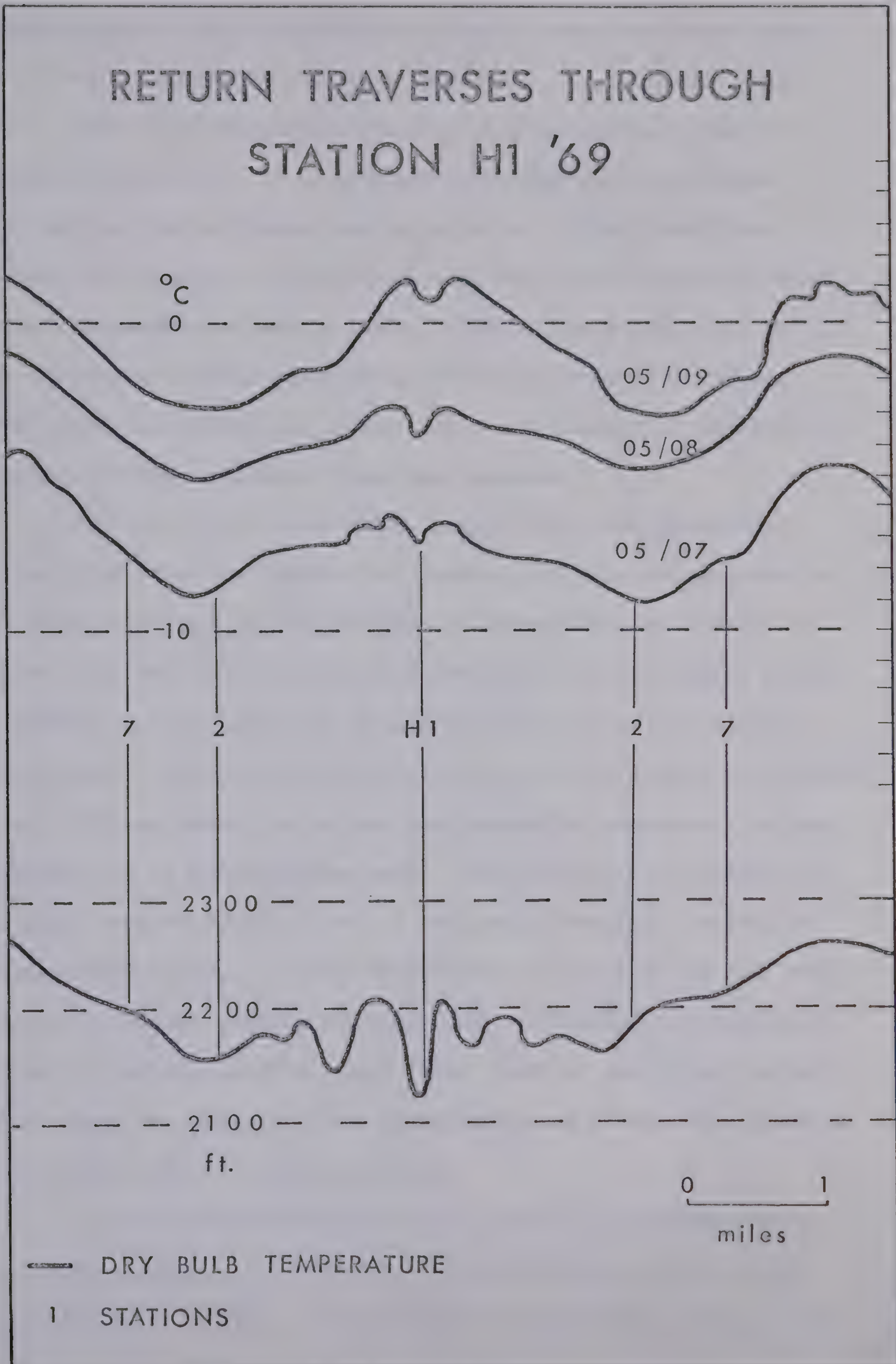

RETURN TRAVERSES THROUGH
STATION H1 '69
°C
0
05 / 09
05 / 08
05 / 07
-10
7
2
H1
2
7
2300
2200
2100
ft.
0
1
miles
DRY BULB TEMPERATURE
1 STATIONS

FIGURE 7.7

climatological level, five different types of study areas were chosen. In all cases, the graphs and maps represent traverses at 30 m.p.h. under clear and relatively calm (5 miles per hour wind) atmospheric conditions. It is in association with these conditions that maximum thermal diurnal variations occur. Cloudy conditions inhibit the incoming solar radiation such that less differential heating of the earth's surface is found. Likewise, wind conditions mix the air strata, thereby eliminating cold or hot spots. Therefore, under clear calm conditions, warmer and colder pockets in relationship to topographical variations become more apparent.

The five areas--Swan Hills, Lesser Slave Lake, Frog Lake, Spring Creek Basin and Hinton-are characteristic of a unique aspect of the larger study region. The location of these areas is shown in Figure 7.8. Swan Hills, rising 2000 feet above the surrounding plains, illustrates primarily thermal topographical variations within forest environments. Lesser Slave Lake, as the name implies, shows the effects, if any, of large water bodies upon the surrounding temperature regimes. Likewise, but on a much smaller scale, Frog Lake notes the effects of the lake temperatures on an area of undulating topography subject to extensive frost damage. Spring Creek Basin, utilized as the test basin for the instrument, denoted the topographic variations in temperature within a relatively uniform forest stand. Lastly, the Hinton Area or better named the Athabasca River Valley notes the effects of a forested river valley upon the thermal patterns.

In conjunction with each of these areas is the examination of the local area which is represented by the reporting station as characteristic of its locale. It has long been thought that because of the

LOCATION OF TRAVERSE SITES WITHIN THE STUDY AREA

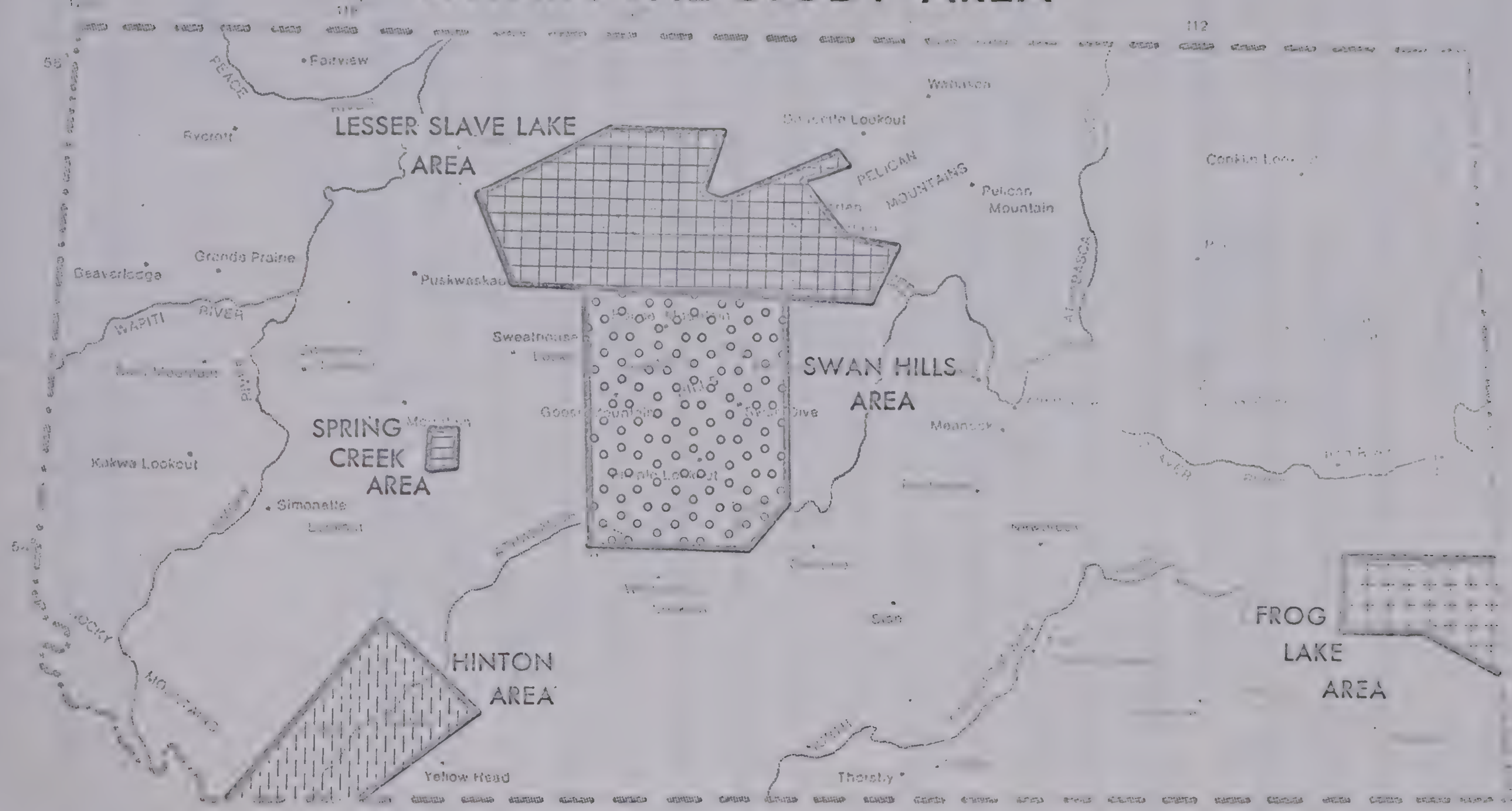


FIGURE 7.8

height and exposed condition of the forestry towers, each of these observing points was not climatically typical of the area surrounding it. In many cases, eg., Swan Dive, this is the case. However, the same can be said for many of the Department of Transport stations, for example Meanook, Hinton, Entrance, Athabasca, Lac la Biche and Wagner. These non-representative stations will become apparent in the presentation of thermal maps later in the Chapter.

Also measured was the dew-point temperature during each set of traverse routes., But because of the variability of moisture upon air mass characteristics, only the occasional dew-point readings will be presented. The graphs for Spring Creek Basin serve as adequate indicators of the expected variability in moisture measurements. Figure 7.4 illustrates the increase in dew-point at station 2 near Spring Creek signifying a relative humidity of 88 per cent.

In attempting to bridge the gap between these micrometeorological recordings within the macroclimatological setting, only macroscale thermo maps will be presented. Minor fluctuations of temperature in response to hollows and crests in the land are to be expected and yet are not of major importance for macrometeorological classification. Consequently, each of the above mentioned five study areas will be presented below in the form of maps and, where needed, additional graphs will be used.

Swan Hills

Radiating outward from the base station--Swan Dive Lookout--six routes were chosen and traversed during June 4 to 16th, 1969. In order to define the observing area of each station, the routes

linked the stations Deer Mountain, House Mountain, Goose Mountain, Fort Assiniboine, Pimple Lookout and Whitecourt. These routes are shown in Figure 7.9.

Figure 7.9

Swan Hills Traverse Routes

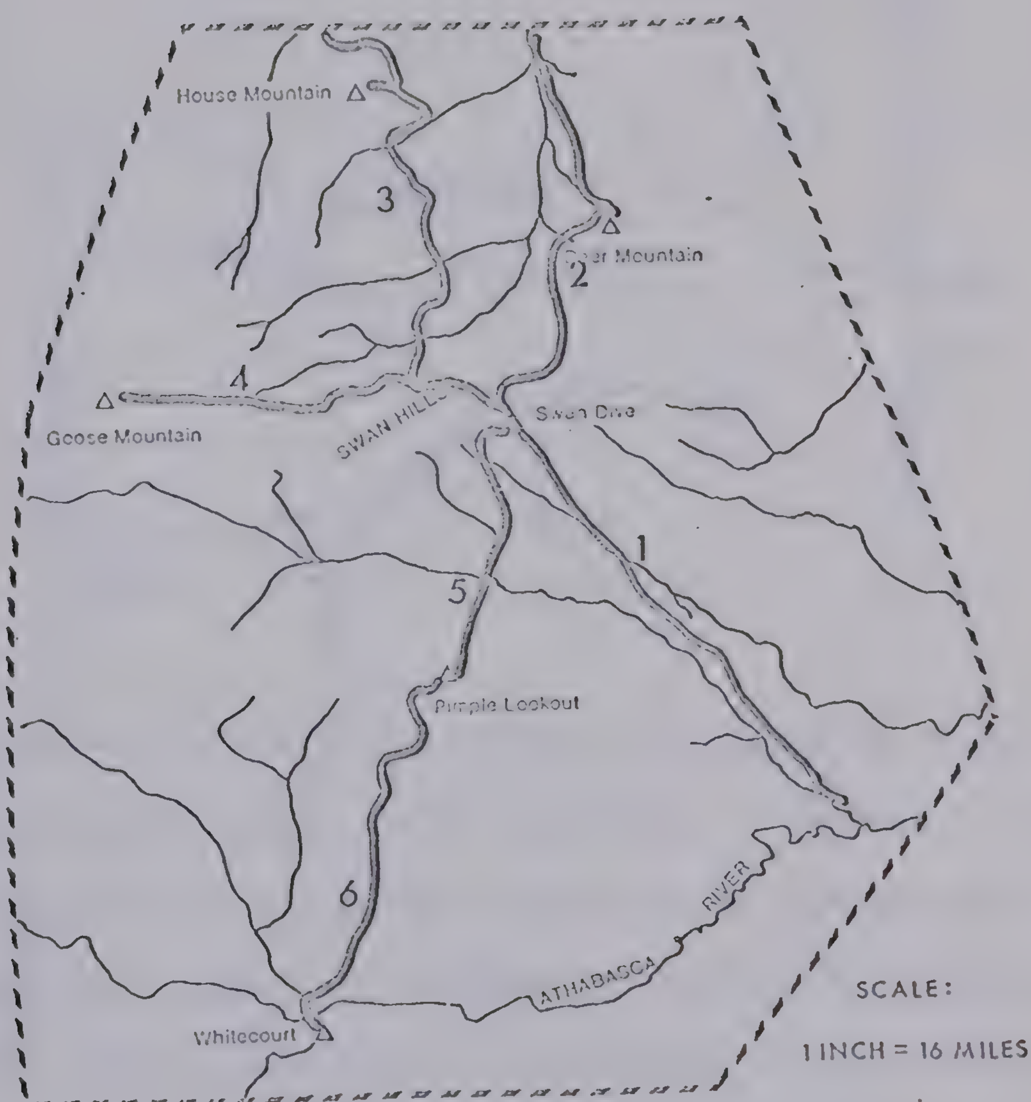
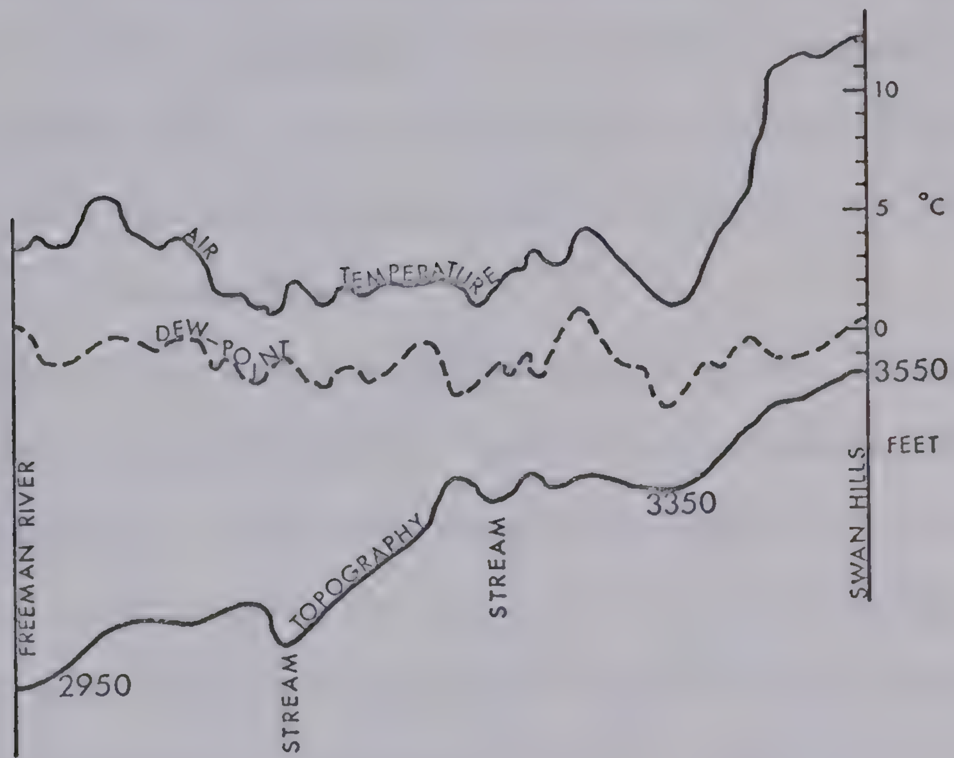


Figure 7.10 shows a section of the route between the Swan Dive Tower and the Pimple Lookout Tower.

Figure 7.10

Swan Hills to Freeman River

Minimum Temperatures June 16



A surprising drop of 11°F. was noted in descending the first 200 feet out from Swan Dive toward the Freeman River. A similar decrease in temperature close to the Freeman River was not experienced. In fact, the opposite was true. The temperature increased upon approaching the river. This would appear to be a result of the warming influence of the water at night upon the surrounding temperatures. It would, therefore, appear that definite cold air drainage results in the initial decrease in temperature off the Swan Hills with the Freeman River being able to have a distinct modifying influence upon this colder air.

The cold air drainage off the higher elevations becomes much

more apparent in the spatial maps of minimum temperature. Figure 7.11 shows the difference in minimum temperatures from the base station Swan Dive. Based upon relatively uniform temperature trends, not simply spot temperatures, decreases of the order of 8°C. in the lower valley portions of the Swan Hills at night are prevalent. Isotherms drawn about each reporting station indicate the uniqueness and non-representativeness of these five stations to describe the climate of the Swan Hills. With the exception of Goose Mountain Lookout, the observing stations within the Swan Hills can be treated at minimum temperatures as representative of very small areas. But is this the case at maximum temperatures?

Figure 7.12 shows the differences in maximum temperatures from the base station Swan Dive. With the exception of Goose Mountain Lookout, uniformity in the temperature characteristics are noted, both in the valley regions and at mountain lookout stations. One other area in the section between Swan Dive Tower and Pimple Lookout exhibits an increase in temperature of 7°C. This is the result of the angle of the south slope at this point allowing it to absorb the maximum amount of incoming solar radiation. The south slope between Swan Dive Lookout and Fort Assiniboine is generally 2°C. warmer mainly due to the more gently sloping topography. Goose Mountain Lookout at the time of maximum temperatures is found to be 2°C. cooler than the other stations. This would appear to be a result of the higher elevation at Goose Mountain--326 feet higher than Swan Dive Tower.

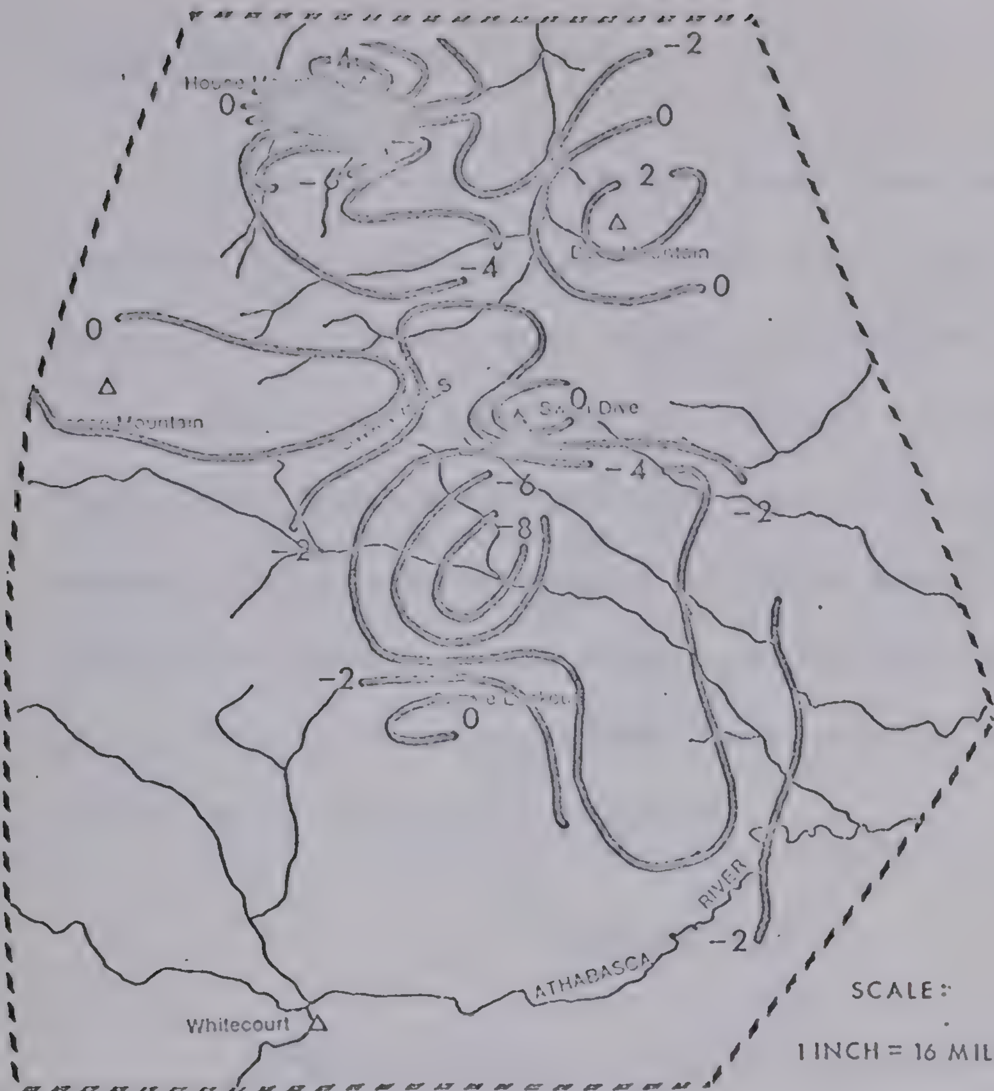


Figure 7.11
Difference in minimum temperatures from the base station - Swan Dive Lookout.

Values in Cent. Degrees

SCALE:

1 INCH = 16 MILES

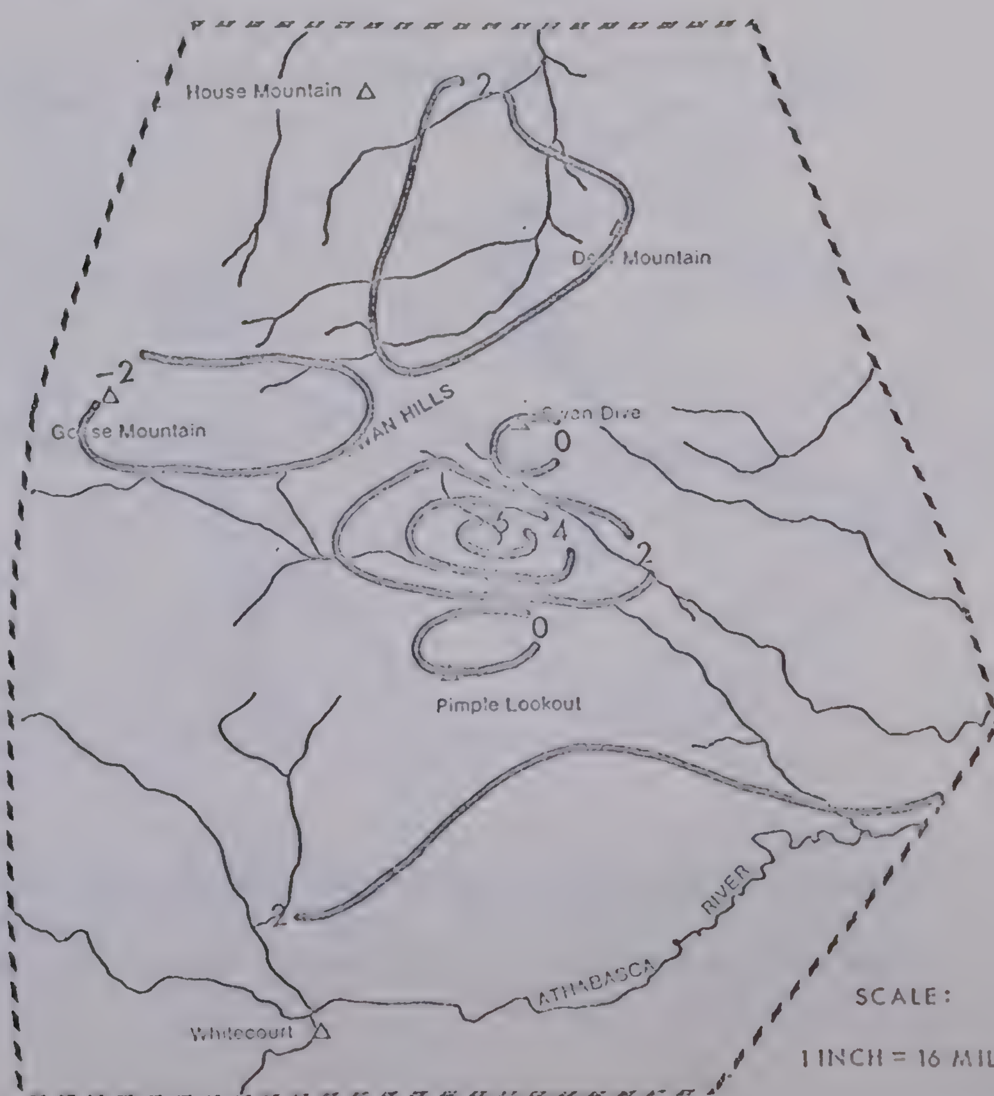


Figure 7.12

Difference in maximum temperatures from the base station - Swan Dive Lookout

SCALE:

1 INCH = 16 MILES

Lesser Slave Lake

Again the traverse results were chosen such that the base stations--Slave Lake and High Praire--are found at the beginning of the routes. The traverses were recorded between the 18th and 26th of August, 1969. Overlapping of the traverse routes, as is shown in Figure 7.13, enabled the resulting temperature differences to be standardized in relationship to the Slave Lake Station. Likewise, duplication of part of the route into the Swan Hills enabled the Slave Lake station to be adjusted such that results between the Slave Lake-Swan Hills areas could be compared.

Figure 7.13

Traverse Routes in the Lesser Slave Lake Area

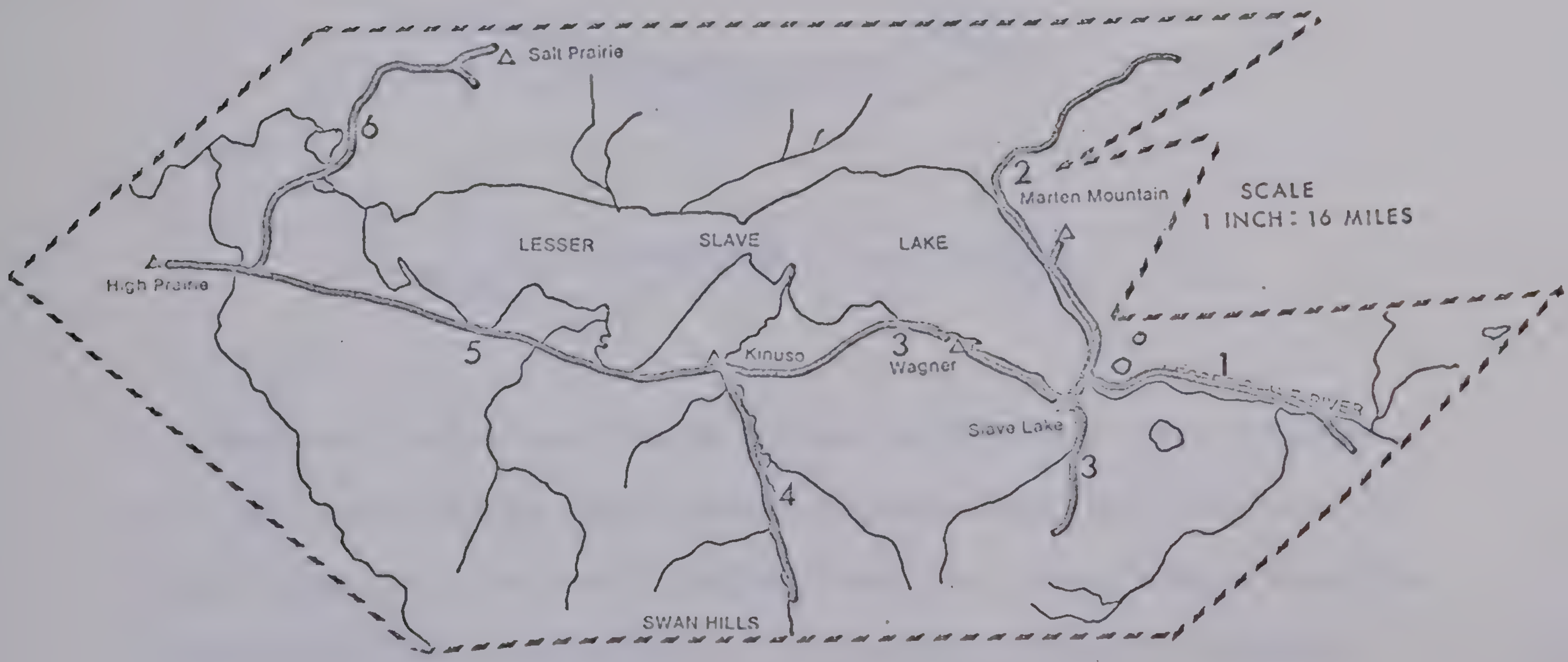


Figure 7.14 shows the minimum temperature traverse from Slave Lake to Wagner on August 21, 1969. Slave Lake is located on the south-

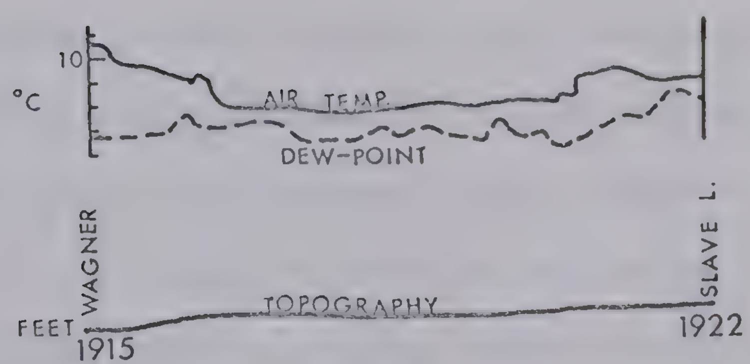
eastern tip of Lesser Slave Lake at an elevation of 1922 feet, whereas Wagner is found on the southern shore at an elevation of 1915 feet. Located directly south and southwest of Wagner are the Sawridge Hills, rising to an elevation of 2500 feet. In contrast, the general topography about the town of Slave Lake is low and marshy with the Lesser Slave River, the outlet to Lesser Slave Lake, found to the north of the town. The traverse of August 21 indicates lower temperatures of the order of 3°C. in the vicinity of the Slave Lake Station.

Figure 7.14

Minimum Temperature Traverse

Slave Lake to Wagner

August 21, 1969.



Assuming that during the time of minimum temperatures, the lake acts as a heat source, then one plausible explanation of the difference in temperatures is as follows. The Sawridge, Flat-top and Marten Mountains encircle the town of Slave Lake. The resulting cold air drainage at nights therefore would accumulate in the lower valley regions--namely, in the area surrounding Slave Lake. Wagner, owing to its close proximity to the Sawridge Hills would not be affected to a large degree by

this downflow of cooler air. The warmer lake air would be sufficient to divert the flow to Slave Lake since the predominant wind direction funnels into the Slave Lake townsite. Therefore, both the warmer lake air mixing with the cooler downvalley air at Slave Lake results in lower temperatures, relative to Wagner and yet warmer than High Prairie. This is illustrated in Figure 7.15, where generally the southern and eastern ends of Lesser Slave Lake exhibit warmer temperatures. Keeping in mind that the predominant direction of the wind is easterly on the lake, it is not surprising to find warmer minimum temperatures in this region.

The maximum temperature distribution for areas surrounding the Lesser Slave Lake are shown in Figure 7.16. During the daytime, Lesser Slave Lake acts as a source of cooler air--the land heating at a faster rate in response to the incoming radiation. It was therefore found by numerous traverses in this area that the southern and eastern portions of the lake's periphery were cooler than the western portions. Outflowing of cool air from the lake, in the direction of the wind off the lake, would therefore, be found in the eastern sections.

In conclusion, owing to the predominant westerly flow of air over Lesser Slave Lake, the eastern portion of the lake and environs are modified both at maximum and minimum temperatures. Higher minimums and lower maximums are characteristic of this easterly region.

Frog Lake Area

Again primarily a study of lake influences, the Frog Lake area,

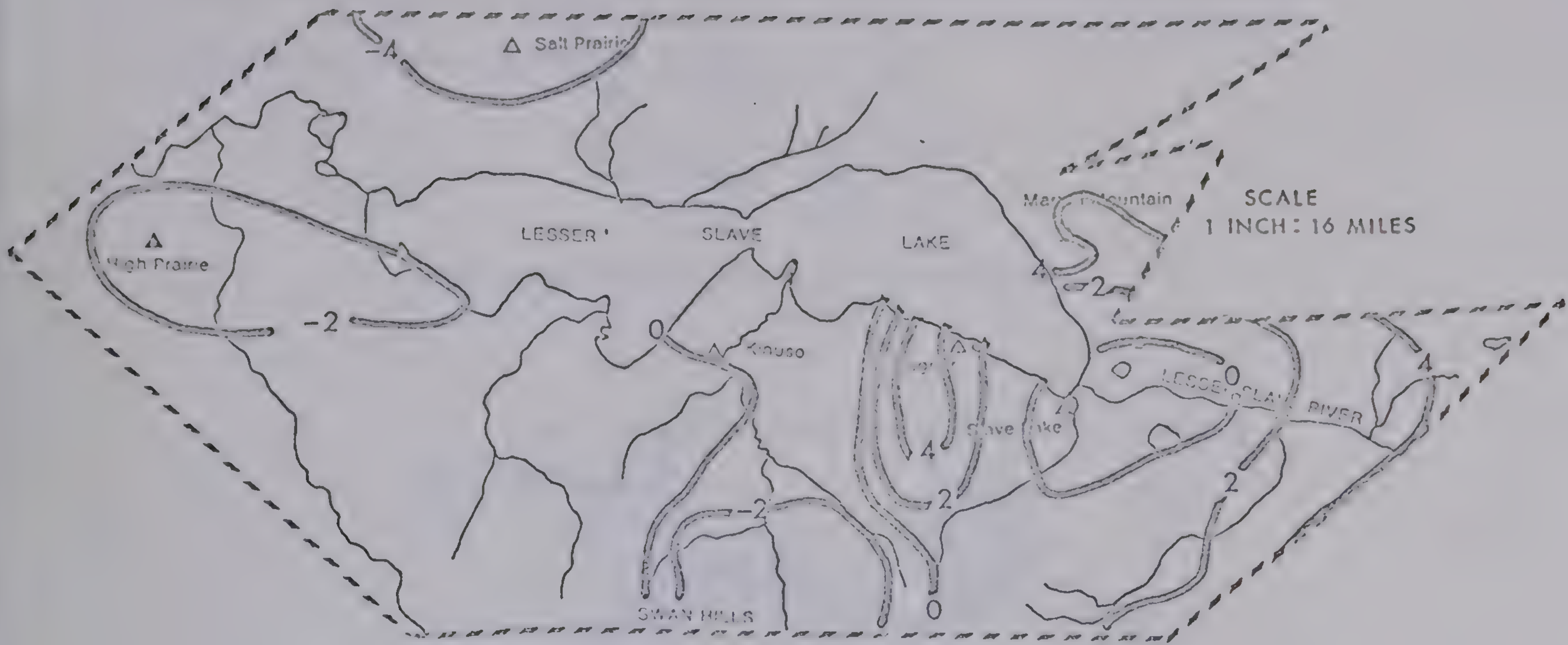


Figure 7.15

Difference in minimum temperatures from the base station - Slave Lake

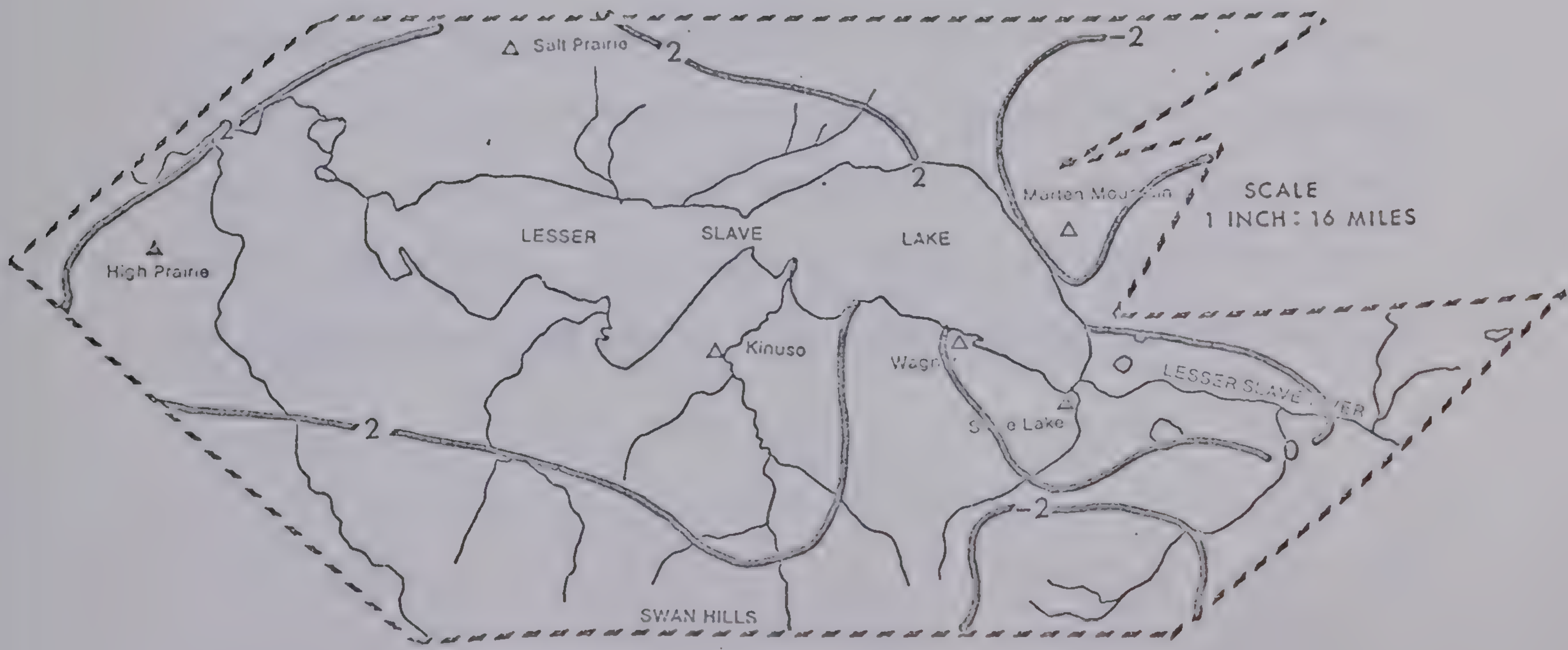


Figure 7.16

Difference in maximum temperatures from the base station - Slave Lake

Values in Cent. Degrees

was studied between May 20th and 24th, 1969. The three traverse routes are shown in Figure 7.17.

Figure 7.17

Traverse Routes in the Frog Lake Area

In the case of the two traverse routes passing through Elk Point, small variations of the order of 1 - 2°C. in response to the topography were noted. As a result, for the purposes of macro-climatological research, the Elk Point station was treated as representing a much larger area than the forest lookout towers (for example, Swan Hills). However, in close proximity to the lake, larger thermal variances were noted. As is shown in Figure 7.18 temperatures at the freezing level were noted to the south and southeast of the lakes.

Figure 7.18

Minimum Temperature

Traverse at Frog Lake

May 23, 1969.

Found in the southern portion of Frog Lake is not only the outlet stream but also a profusion of low marshy depressions. Consequently, the influence of the cooler lake temperature at night is sufficient to cause an abundance of frost pockets in association with the lake regions. To the west of the lake, where higher land is found, temperatures well above freezing are noted. The cooler lake air is unable to influence these minimum temperatures except in places where small rivers or streams dissect the western regions. A drop of 3°C. is

noted in approaching a small creek which flows from the west into Frog Lake. Likewise, Sputinow, the Indian Reserve settlement, is affected to a lesser degree by the cooler lake air. This is again due to the higher elevation of the settlement.

Consequently, unlike the warming influence of Lesser Slave Lake at night in August, the lakes in May, for example Frog Lake, exert cooling influences upon the surrounding lower land. The lakes thus have a substantial impact upon the surrounding minimum temperatures dependent upon the time of year. In the spring with the land unfrozen the lakes act as a coolant. But as the lake temperatures warm up by early fall, these bodies of water act as a heat source upon minimum temperatures. Likewise, the influence of muskeg was noted by the author as having definite cooling effects upon temperature - to the order of 10° F.

Spring Creek Basin

Spring Creek Basin was traversed between May 6th and May 10th, 1969. The results for these days are noted previously in this Chapter as Figures 7.4, 7.5, 7.6 as indicative of the method of thermo dew-point recording. Consequently, little will be said here about the variations within this basin--the highlights have already been touched upon. The thermal spatial map appears in Figure 7.19 with mean daily temperature averages being presented. Uniformity in maximum temperatures and variability in minimum temperatures is able to account for minor fluctuations on a mean daily basis. Again, as with Frog Lake in May, proximity to a water body--Spring Creek--is sufficient to produce noticeable cooling effects upon the temperature. Consequently, for the early portion of the summer months, cooling influences, not extending to a

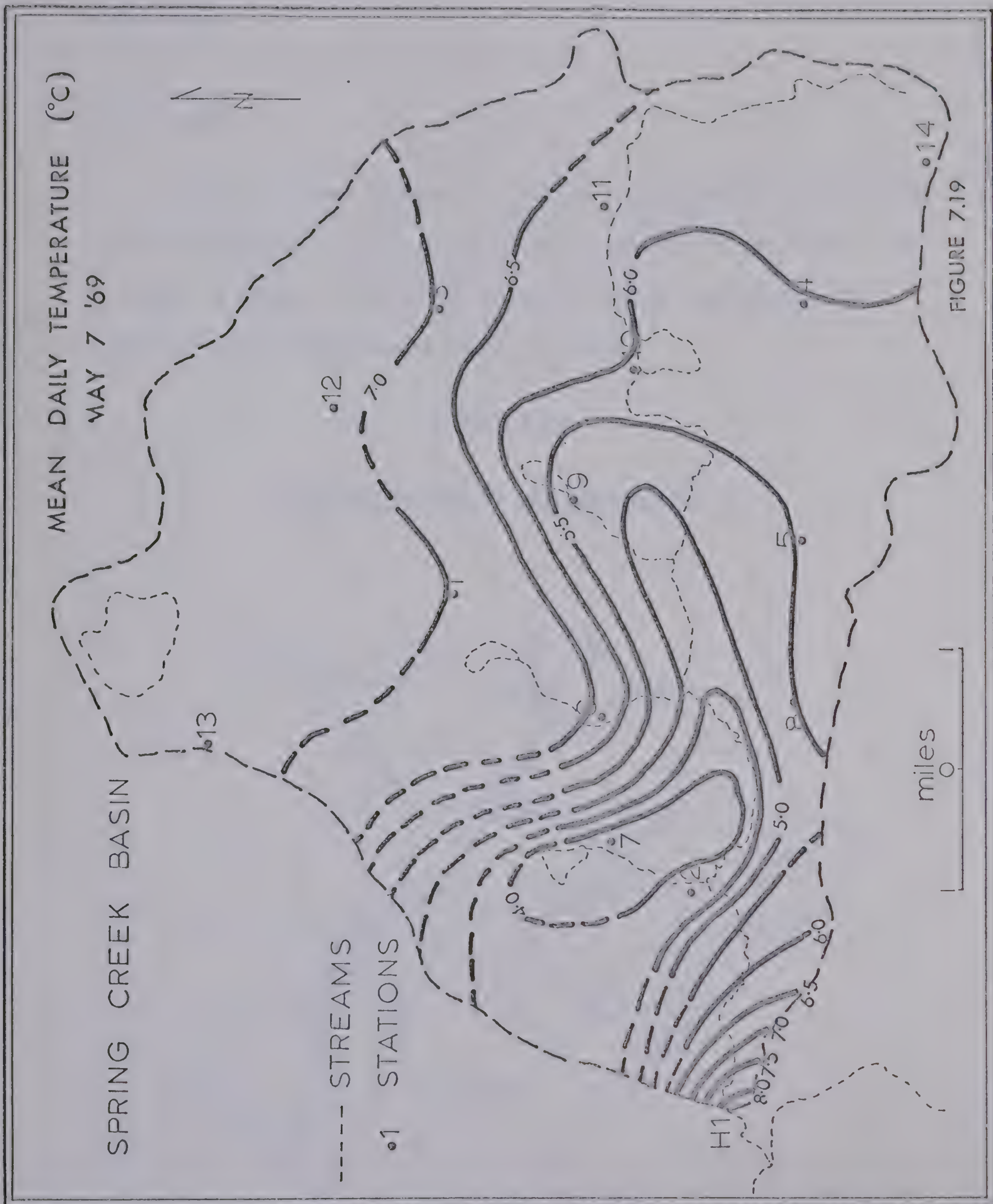

SPRING CREEK BASIN
MEAN DAILY TEMPERATURE (°C)
MAY 7 '69
N
STREAMS
STATIONS
miles
0
1
13
12
3
1
9
11
6
5
8
7
2
4
14
H1
7.0
6.5
6.0
5.5
5.0
4.0
6.0
6.5
7.0
7.5
8.0

FIGURE 7.19

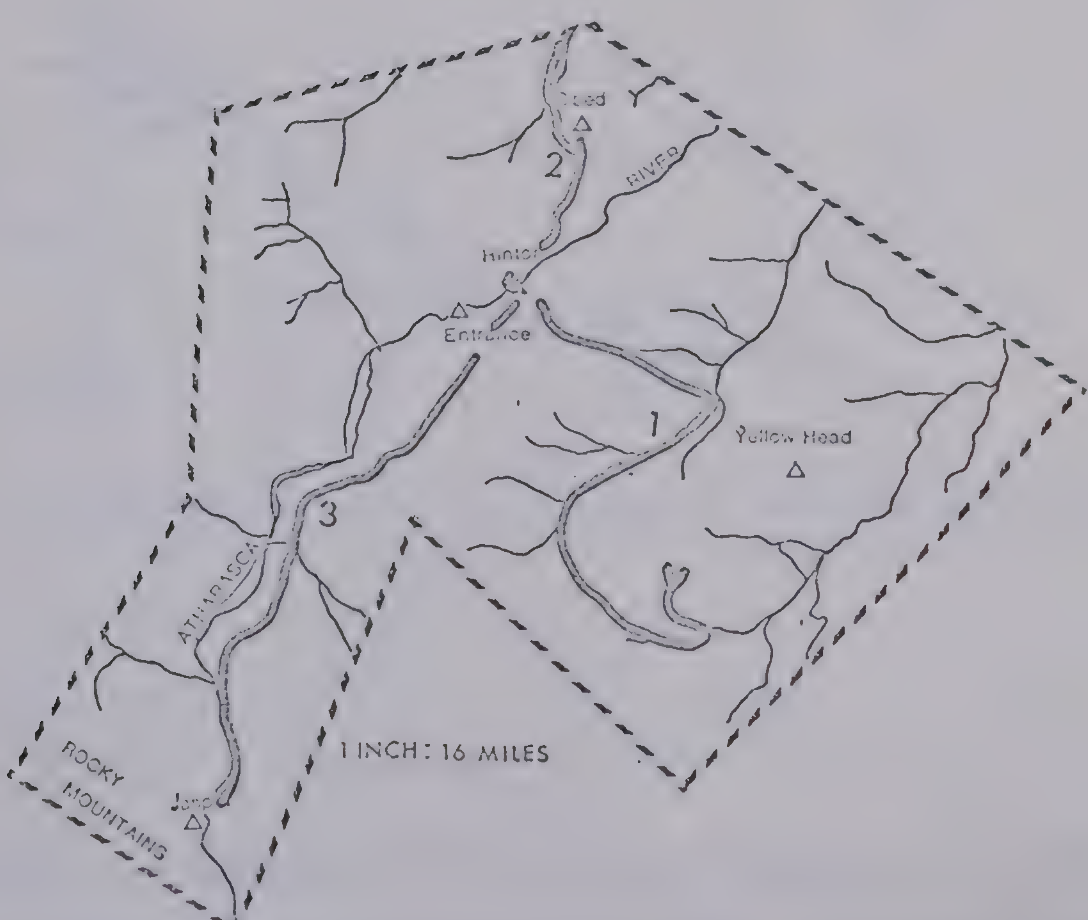
great distance, are typical of the water bodies and rivers within the study area.

Hinton Area

The last area of study by mobile thermo dew-point recording is the Hinton Area or better named the Athabasca River Valley. As is shown in Figure 7.20, three traverse routes were chosen and studied between September 3rd and 9th, 1969.

Figure 7.20

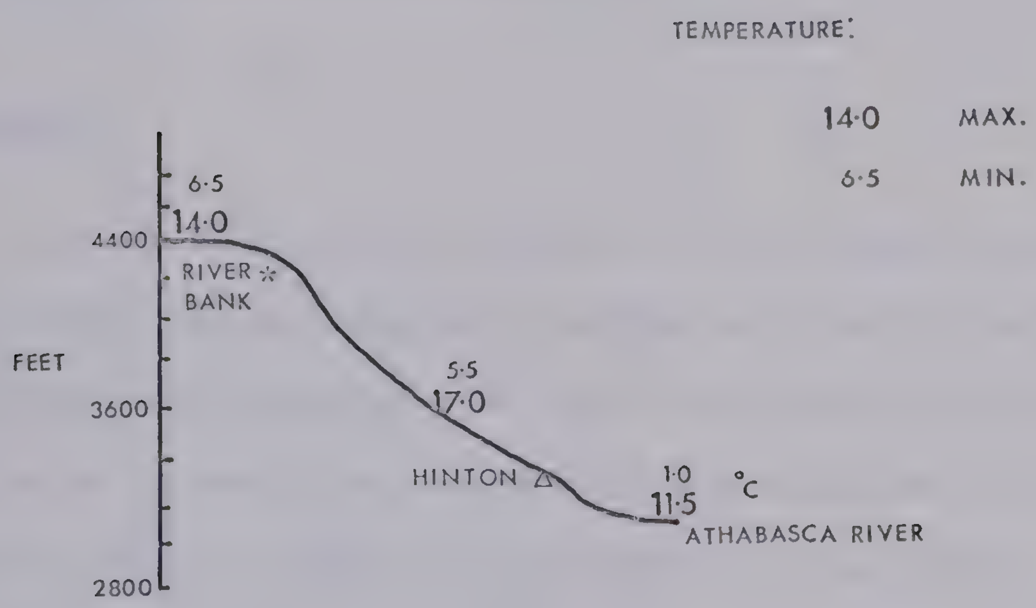
Traverse Routes in the Hinton Area



As an illustration of the thermal differences to be found at both maximum and minimum temperatures within the river valley, Figure 7.21 shows the cross-sectional analysis.

Figure 7.21

Cross-Sectional View of the Thermal Differences in Response to Height Change September, 1969.



* RIVER BANK location is 1.8 miles to the south of Hinton.

Characteristic of the water bodies, cooler temperatures are again found in close proximity to the Athabasca River. At minimum temperatures a sharp decline in temperature from 5.5°C. to 1°C. is found in association with a height decrease of 400 feet. At maximum temperatures, the

mid-valley region portrays the warmest temperature with both the river and the top of the river bank at cooler temperatures. Since the observing station at Hinton is found in this mid-valley region, it is therefore warmer on a mean daily basis than the surrounding area beyond the river valley. Consequently, stations such as Hinton and Entrance will be treated as characteristic of river valley stations--not representative of larger areas.

The macroclimatic thermal maps are again illustrated for the traverse routes in Figures 7.22 and 7.23. Utilizing Hinton as the base station, the subsequent differences in temperature are illustrated for both maximum and minimum temperatures.

Conclusions

One of the secondary objectives of this thesis was the evaluation of mobile thermo dew-point recording as a tool in the delineating of macroclimatic boundaries. In view of the results presented above there can be no doubt that the physical variations have a distinct influence upon the climatic structure which in turn affects the extent of the representativeness of the reporting stations. As a result, the guidelines of use of these traverses are outlined in a future chapter. Here it is sufficient to state that the mobile detection of spatial thermal variances was able to help substantially in interpolation of the numerical results and in the author's understanding of the climatic interactions within the study region.

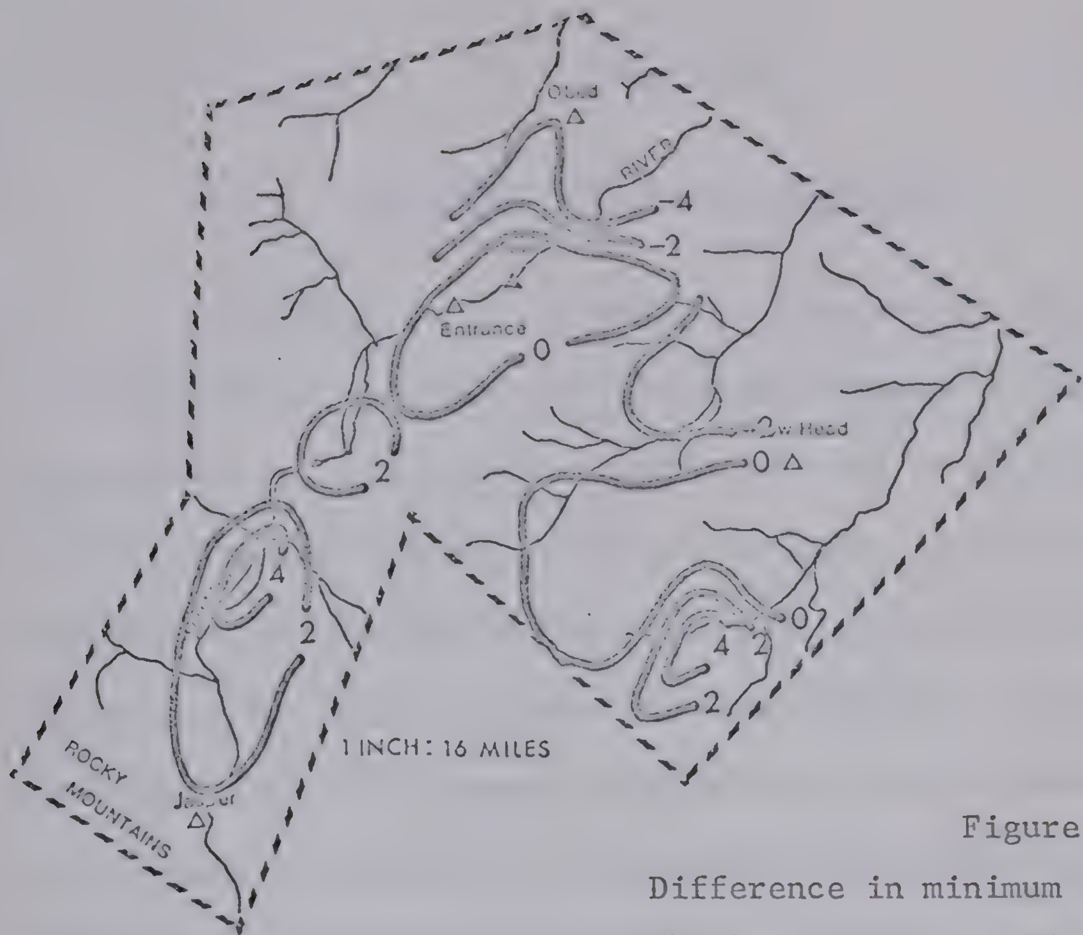


Figure 7.22

Difference in minimum temperatures from the base station - Hinton

Values in Cent. Degrees

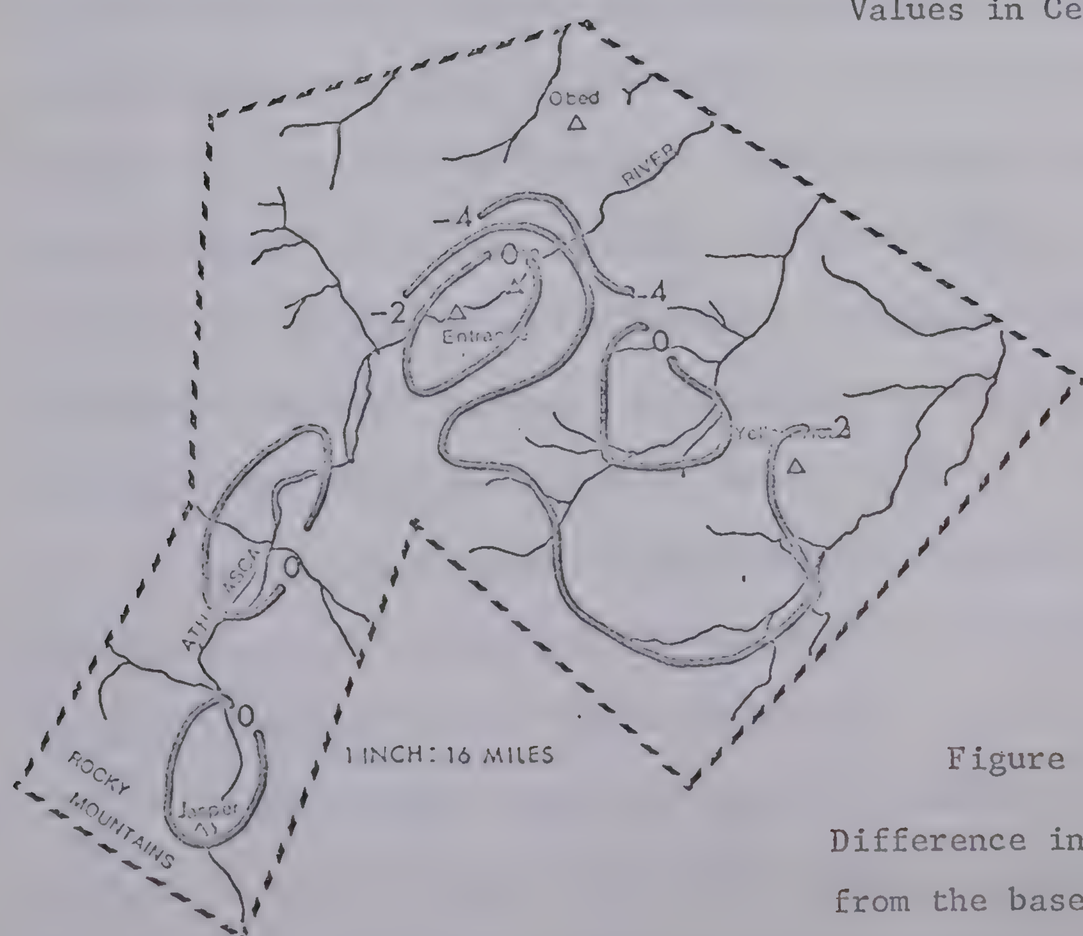


Figure 7.23

Difference in maximum temperatures from the base station - Hinton

Chapter 8

Method of Statistical Analysis

Subjective and/or objective evaluation are the two classification procedures available for grouping homogeneous climatic areas. Homogeneous is used here as meaning the area in which the stations exhibit the most similar climatic constancy. A built-in bias by the classifier is inherent in the subjective grouping of stations by clustering the data into predetermined classes. Consequently, since the input data lacks this initial subjectivity, objective classification became the technique thought best to determine similar climates directly from the raw input data.

Several methods of statistical discrimination between values are available such as the use of--polynomials, simple linear regression, multiple regression, principal-component analysis, factor analysis, and multivariate discriminate analysis. The latter technique assumes a priori grouping of the station variables thereby demanding pre-defined class limits, not inherent in other statistical techniques. Newnham, previously noted in Chapter 2, offers a plausible solution--principal-component analysis, with subsequent comparison of the plotted orthonormalized variables for 70 stations in British Columbia. Not unlike the theory of principal-component analysis, factor analysis was the technique chosen and utilized herein for statistical classification given the host of input variables.

Fundamentally, factor analysis is a method of reducing large numbers of input indices to a smaller number of meaningfully significant indices. The basic model for principal-component analysis is

represented as:

$$Z_j = \sum_{k=1}^{p} W_{jk} Y_k^1 \qquad j,k = 1, 2, \ldots p$$

where W_{jk} represents the normalized eigenvectors and Y_k^1 represents the vector of standardized components. Differing somewhat, the factor analysis model is presented as:

$$Z_j = \sum_{r=1}^{m} v_{jr} f_r + e_j \qquad j = 1, 2, \ldots p; m \leq p$$

where v_{jr} represents the normalized eigenvectors, f_r represents the standardized factors and e_j is the variance associated with each factor. In each of the above cases, Z_j is the standardized original variable. Insertion of the communalities at the beginning of the analysis into the correlation matrix (R) distinguishes the technique of factor analysis from the principal-component analysis. Subsequent extraction of the eigenvalues and eigenvectors ensues, thereby labelling the technique--principal axis factor analysis. No a priori grouping of the input data is needed.

Communalities are the common variance accounted for by the factors. Each factor, in turn, involves an estimate of the variance associated with each variable. Eigenvalues are defined as the roots of the characteristic equation

$$|A - \lambda I| = 0$$

where A is the correlation matrix, I is the identity matrix and λ is a scalar (eigenvalue). Associated with each eigenvalue will be solution vectors usually referred to as eigenvectors.

Data Input

Compiled from the available climatic parameters, a list of the 75 variables, serving as input for the factor analysis, is outlined in Table 8.1. Mathematically, the raw input is represented by

$$X_{ij} \qquad \begin{array}{l} i = 1, 2, \ldots 53 \\ j = 1, 2, \ldots 75 \end{array}$$

where i is the number of stations varying from 1 to 53 and j is the number of variables per station varying from 1 to 75.

Factor Analysis

The first stage in the computational procedure is the calculation of grand means for each of the 75 variables. Table 8.2 presents these values according to the formula

$$\overline{X}_j = \sum_{j=1}^{n} X_{ij} \,/n \qquad \begin{array}{l} i = 1, 2, \ldots 53 \\ j = 1, 2, \ldots 75 \end{array}$$

where n is the number of cases or stations. Of particular interest is the mean frost-free period of 102 days as compared to the killing frost-free period of 131 days. This is an average mean difference of 29 days between the damage and the killing stage of frost in relationship to vegetational growth.

Table 8.1

INPUT CLIMATIC VARIABLES FOR STATISTICAL ANALYSIS

REFERENCE VARIABLE NUMBER	VARIABLE DESCRIPTION
1	Elevation in feet above mean sea level
2	Latitude in degrees and minutes North
3	Longitude in degrees and minutes West
4	May Mean Daily Temperature in °F
5	June Mean Daily Temperature in °F
6	July Mean Daily Temperature in °F
7	Aug Mean Daily Temperature in °F
8	Sept Mean Daily Temperature in °F
9	May Mean Total Precipitation
10	June Mean Total Precipitation
11	July Mean Total Precipitation
12	Aug Mean Total Precipitation
13	Sept Mean Total Precipitation
14	May Mean Daily Maximum Temperature in °F
15	June Mean Daily Maximum Temperature in °F
16	July Mean Daily Maximum Temperature in °F
17	Aug Mean Daily Maximum Temperature in °F
18	Sept Mean Daily Maximum Temperature in °F
19	May Mean Daily Minimum Temperature in °F
20	June Mean Daily Minimum Temperature in °F
21	July Mean Daily Minimum Temperature in °F
22	Aug Mean Daily Minimum Temperature in °F
23	Sept Mean Daily Minimum Temperature in °F
24	May Mean Number of days above 32°F
25	June Mean Number of days above 32°F
26	July Mean Number of days above 32°F
27	Aug Mean Number of days above 32°F
28	Sept Mean Number of days above 32°F
29	May Mean Number of days above 42°F
30	June Mean Number of days above 42°F

REFERENCE VARIABLE NUMBERS	VARIABLE DESCRIPTION
31	July Mean Number of days above 42°F
32	Aug Mean Number of days above 42°F
33	Sept Mean Number of days above 42°F
34	May Mean Number of days above 28°F
35	June Mean Number of days above 28°F
36	July Mean Number of days above 28°F
37	Aug Mean Number of days above 28°F
38	Sept Mean Number of days above 28°F
39	May Degree-days above 28°F
40	June Degree-days above 28°F
41	July Degree-days above 28°F
42	Aug Degree-days above 28°F
43	Sept Degree-days above 28°F
44	May Degree-days above 32°F
45	June Degree-days above 32°F
46	July Degree-days above 32°F
47	Aug Degree-days above 32°F
48	Sept Degree-days above 32°F
49	May Degree-days above 42°F
50	June Degree-days above 42°F
51	July Degree-days above 42°F
52	Aug Degree-days above 42°F
53	Sept Degree-days above 42°F
54	May Potential Evapotranspiration in inches
55	June Potential Evapotranspiration in inches
56	July Potential Evapotranspiration in inches
57	Aug Potential Evapotranspiration in inches
58	Sept Potential Evapotranspiration in inches
59	May Actual Evapotranspiration in inches
60	June Actual Evapotranspiration in inches
61	July Actual Evapotranspiration in inches
62	Aug Actual Evapotranspiration in inches

REFERENCE VARIABLE NUMBER	VARIABLE DESCRIPTION
63	Sept Actual Evapotranspiration in inches
64	May Water Deficit in inches
65	June Water Deficit in inches
66	July Water Deficit in inches
67	Aug Water Deficit in inches
68	Sept Water Deficit in inches
69	May Mean Day length in hours and minutes
70	June Mean Day length in hours and minutes
71	July Mean Day length in hours and minutes
72	Aug Mean Day length in hours and minutes
73	Sept Mean Day length in hours and minutes
74	Frost-Free Period in days
75	Killing Frost-Free Period in days

Table 8.2

GRAND MEANS - STANDARD DEVIATIONS

VARIABLE REFERENCE NUMBER	GRAND MEANS*	STANDARD DEVIATIONS* (±)
1	2658.1	819.0
2	54.4	0.7
3	114.8	2.5
4	47.7	1.9
5	54.3	2.0
6	58.8	2.2
7	56.9	2.0
8	47.9	1.8
9	1.8	0.4
10	3.1	0.6
11	3.2	0.6
12	3.0	0.6
13	1.7	0.4
14	59.0	3.2
15	65.6	3.2
16	70.1	3.5
17	67.9	3.3
18	58.4	3.0
19	37.0	2.3
20	43.7	2.4
21	48.0	2.4
22	46.5	2.2
23	38.2	2.1
24	22.2	2.7
25	28.8	1.0
26	30.6	0.5
27	30.6	0.3
28	23.3	2.0
29	7.5	3.1
30	17.8	3.9
31	26.1	3.0
32	23.4	3.6
33	9.0	2.9
34	27.0	1.7
35	29.6	0.5
36	30.7	0.5
37	30.9	0.0
38	26.9	1.1
39	615.2	59.9
40	794.0	61.9

Table 8.2 continued

VARIABLE REFERENCE NUMBER	GRAND MEANS*	STANDARD DEVIATIONS* (±)
41	959.6	69.2
42	899.4	63.5
43	609.2	49.1
44	493.9	59.3
45	674.4	61.9
46	836.5	68.9
47	775.5	63.5
48	490.8	48.4
49	216.5	49.0
50	378.6	60.7
51	529.8	68.1
52	467.7	63.8
53	220.5	39.7
54	2.8	0.1
55	3.8	0.1
56	4.5	0.1
57	3.9	0.1
58	2.3	0.0
59	2.8	0.1
60	3.5	0.1
61	3.6	0.4
62	2.9	0.4
63	1.6	0.2
64	0.0	0.0
65	1.0	0.7
66	1.8	0.6
67	1.9	0.4
68	1.3	0.3
69	15.9	0.1
70	17.0	0.2
71	16.4	0.1
72	14.6	0.0
73	12.5	0.0
74	101.6	16.4
75	131.3	12.3

*for units of measurement refer to Table 8.1

The degree of variability of the station values from the above overall means are outlined in Table 8.2 according to the formula:

$$S_j = \frac{\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2}{N-1}$$

where $\bar{x}$, is the mean, as calculated above. Little variation in the frost-free days can be expected as indicated by the frost-free deviations of ±16.4 days as compared to the killing frost-free deviations of ±12.3 days.

Independent of the above means and standard deviations, the correlation coefficients represent the interrelationship between each pair of the 75 input variables. Normalization denotes each variable having a mean of zero and unit variance such that the resulting correlation coefficients lack units of measurement. Defined by the general formula:

$$r_{ij} = \frac{\sum_{\alpha=1}^{n} (x_{\alpha 1} - \bar{x}_i)(x_{\alpha j} - \bar{x}_j)}{\sum_{\alpha=1}^{m} (x_{\alpha 1} - \bar{x}_i)^2 \; \sum_{\alpha=1}^{m} (x_{\alpha j} - \bar{x}_j)^2}$$

the symmetrical matrix of correlation coefficients is shown in Table 8.3. The technique followed here provides adjustment of the diagonal elements according to the following formula:

$$R_1^2 = 1 - 1/r_{ii} \qquad (i = 1, 2, \ldots 53)$$

where r^{ii} are the diagonal elements of the inverse of r_{ij}.

Referring to Table 8.1 for the variable reference numbers and description and Table 8.3 for the intercorrelations of these variables, the amount of dependence of one variable upon another is noted. The order of each variable found within each row follows the same sequence order as noted in Table 8.1 increasing horizontally from variable 1 to

Table 8.3

Correlation Coefficients of the Input Climatic Variables

(see Table 8.1 and the text)

CORRELATION COEFFICIENTS

ROW 1

1.00000	-0.16668	0.47090	-0.71635	-0.69576	-0.64214	-0.73624	-0.49173	0.70839	0.78947
0.55705	0.76413	0.52333	-0.85388	-0.82021	-0.68580	-0.78612	-0.69543	-0.03520	-0.11612
-0.23228	-0.19450	0.02319	-0.06172	0.01349	0.12595	-0.17867	-0.06391	-0.09574	-0.26778
-0.26198	-0.24657	-0.00959	0.09455	0.32656	0.17501	0.19197	-0.03912	-0.73130	-0.71702
-0.69238	-0.73414	-0.66583	-0.73498	-0.72192	-0.70220	-0.73523	-0.66454	-0.71980	-0.74430
-0.72993	-0.73408	-0.54964	-0.70467	-0.70044	-0.72080	-0.73375	-0.51339	-0.72972	0.13263
0.61171	0.57585	0.57977	0.11911	-0.25176	-0.20951	-0.29519	0.20798	-0.19334	-0.16072
-0.17076	-0.19503	-0.25639	-0.03447	0.08334					

ROW 2

-0.16668	1.00000	0.23170	-0.03402	-0.06519	-0.10102	-0.08085	-0.23870	-0.15348	-0.03455
0.22901	-0.28370	-0.25910	-0.23705	-0.21758	-0.32362	-0.28518	-0.36837	0.24253	0.14543
0.19345	0.22548	0.17920	0.23909	0.14444	-0.02390	0.26947	0.29011	0.23277	0.17018
0.26296	0.25434	0.22892	0.22465	-0.25972	-0.10130	-0.13910	0.13119	-0.02381	-0.06331
-0.10025	-0.09525	-0.07962	-0.01998	-0.06070	-0.09653	-0.09451	-0.08110	-0.02390	-0.05957
-0.09369	-0.11201	-0.09304	-0.09059	0.00966	-0.09081	-0.07060	-0.14789	-0.10418	-0.02620
0.07657	-0.19753	-0.28648	0.15252	0.16733	0.02750	0.23072	-0.09446	0.98543	0.95794
0.99016	0.98625	0.94556	0.37934	0.28655					

ROW 3

0.47090	0.23170	1.00000	-0.21112	-0.22210	-0.21093	-0.27994	-0.04569	0.32317	0.25352
-0.02339	0.08438	-0.14985	-0.36619	-0.30242	-0.23184	-0.30022	-0.18886	0.12289	-0.00384
-0.11367	-0.09866	0.09952	0.04655	0.12178	0.26972	-0.04140	0.06446	0.03743	-0.17256
-0.18498	-0.18083	0.05919	0.26420	0.26345	0.31710	0.33178	0.01001	-0.23737	-0.24949
-0.26599	-0.27964	-0.09377	-0.24777	-0.25544	-0.27770	-0.28032	-0.09633	-0.29014	-0.28820
-0.31721	-0.29512	-0.13490	-0.23962	-0.20256	-0.38590	-0.31925	0.06845	-0.26128	0.02900
0.06920	-0.02860	-0.05545	0.22958	-0.01012	0.04156	-0.01032	0.01226	0.21948	0.19585
0.21967	0.20542	0.16320	0.15064	0.21238					

ROW 4

-0.71635	-0.03402	-0.21112	1.00000	0.96335	0.90562	0.94899	0.82777	-0.51859	-0.64881
-0.64101	-0.63988	-0.41250	0.80462	0.79874	0.74752	0.76870	0.70889	0.58093	0.60799
0.63588	0.59605	0.46604	0.50641	0.38645	0.18662	0.43020	0.44402	0.59633	0.63564
0.52519	0.53182	0.46968	0.38093	0.04240	0.09222	0.13418	0.45590	0.99778	0.96838
0.92689	0.94371	0.95560	0.99643	0.96912	0.93035	0.94399	0.95677	0.98225	0.97263
0.93793	0.93935	0.95556	0.90281	0.91448	0.87175	0.87480	0.74310	0.89689	-0.19895
-0.58270	-0.56501	-0.40428	0.33911	0.44421	0.27447	0.33511	-0.22720	0.01409	-0.04586
-0.02130	0.01107	0.06434	0.33961	0.31574					

ROW 5

-0.69576	-0.06519	-0.22210	0.96335	1.00000	0.96992	0.96199	0.82380	-0.45988	-0.63877
-0.60575	-0.60617	-0.38712	0.79416	0.81688	0.79307	0.77870	0.71593	0.52732	0.64055
0.67517	0.59897	0.44814	0.45708	0.43394	0.28072	0.42885	0.40503	0.54170	0.64189
0.55521	0.53926	0.44287	0.32689	0.16994	0.19703	0.19221	0.42199	0.95561	0.99587
0.97778	0.95889	0.93526	0.95254	0.99444	0.97780	0.95876	0.93596	0.93607	0.98470
0.97449	0.94908	0.93094	0.81466	0.95245	0.90997	0.87793	0.69091	0.81182	-0.08228
-0.52752	-0.54620	-0.40633	0.25939	0.36055	0.26591	0.35812	-0.16012	-0.01756	-0.07841
-0.05496	-0.02061	0.03089	0.30443	0.26632					

ROW 6

-0.64214	-0.10102	-0.21093	0.90562	0.96992	1.00000	0.92180	0.77440	-0.41585	-0.56476
-0.57364	-0.55488	-0.34668	0.76641	0.81083	0.83246	0.75933	0.68912	0.46387	0.59069
0.66118	0.54840	0.40055	0.39953	0.42843	0.41236	0.44183	0.37034	0.46075	0.57737
0.52716	0.49294	0.38526	0.28483	0.21343	0.32909	0.29320	0.41564	0.89096	0.95443
0.98673	0.91876	0.88592	0.88584	0.95095	0.98228	0.91834	0.88609	0.86353	0.93371
0.96557	0.90459	0.87362	0.74239	0.91312	0.90748	0.84444	0.61001	0.74167	-0.03778
-0.48873	-0.50790	-0.39653	0.20616	0.32750	0.31261	0.33160	-0.14309	-0.05489	-0.10875
-0.08660	-0.05839	-0.00297	0.24998	0.22975					

ROW 7

-0.73624	-0.08085	-0.27994	0.94899	0.96199	0.92180	1.00000	0.86238	-0.50312	-0.64705
-0.65646	-0.62272	-0.34836	0.81253	0.81881	0.76627	0.82568	0.75836	0.48224	0.57930
0.63752	0.60636	0.44601	0.40807	0.32869	0.09705	0.39245	0.38346	0.52095	0.61076
0.53678	0.53214	0.44477	0.25851	0.00556	-0.00217	0.08681	0.42080	0.95223	0.97440
0.95618	0.99769	0.94915	0.95246	0.97638	0.96199	0.99769	0.95012	0.94596	0.98169
0.97725	0.99117	0.94933	0.81189	0.90299	0.92770	0.94466	0.71579	0.81033	-0.10135
-0.55684	-0.53113	-0.41309	0.23136	0.33341	0.29065	0.32478	-0.12974	-0.04427	-0.08375
-0.06868	-0.04277	0.00304	0.27736	0.23564					

ROW 8

-0.49173	-0.23870	-0.04569	0.82777	0.82380	0.77440	0.86238	1.00000	-0.30263	-0.47353
-0.67333	-0.42631	-0.28041	0.67208	0.67016	0.63719	0.69977	0.71483	0.46454	0.53524
0.53983	0.53689	0.52643	0.36870	0.30402	0.11080	0.29151	0.37053	0.49438	0.51562
0.41256	0.43534	0.45844	0.27920	0.11987	0.04250	0.15117	0.42454	0.82327	0.83329
0.79461	0.86175	0.88219	0.82034	0.83460	0.79803	0.86113	0.88225	0.79974	0.83057
0.80627	0.85105	0.86895	0.68855	0.74646	0.74116	0.76254	0.71960	0.68023	-0.05035
-0.50407	-0.38600	-0.21616	0.28770	0.25310	0.26673	0.26258	-0.20712	-0.21983	-0.23607
-0.23747	-0.22409	-0.18004	0.25926	0.23996					

ROW 9

0.70839	-0.15348	0.32317	-0.51859	-0.45988	-0.41585	-0.50312	-0.30263	1.00000	0.66556
0.53968	0.62363	0.41213	-0.60961	-0.55981	-0.44232	-0.53952	-0.50836	-0.05148	-0.07200
-0.19021	-0.14681	0.03754	-0.06043	0.02159	0.08602	-0.07218	-0.03347	-0.08937	-0.16757
-0.18105	-0.15641	0.02578	0.06367	0.31456	0.12778	0.19169	0.03886	-0.53350	-0.47280
-0.45258	-0.49831	-0.44120	-0.53779	-0.47645	-0.46084	-0.49985	-0.44158	-0.54884	-0.51121
-0.48753	-0.51267	-0.45308	-0.65138	-0.47661	-0.46655	-0.53717	-0.39858	-0.66883	0.52088
0.68843	0.54469	0.59290	0.04310	-0.39158	-0.30526	-0.04331	0.02141	-0.15502	-0.13078
-0.13007	-0.14292	-0.23175	-0.03118	0.10852					

ROW 10

0.78947	-0.03455	0.25352	-0.64881	-0.63877	-0.56476	-0.64705	-0.47353	0.66556	1.00000
0.59585	0.77726	0.62915	-0.76925	-0.75264	-0.63288	-0.71396	-0.74134	-0.04140	-0.11399
-0.17530	-0.13919	0.04785	-0.05476	-0.05921	0.04568	-0.14085	-0.03635	-0.08045	-0.20256
-0.17991	-0.18631	0.00105	0.07057	0.19420	0.03140	-0.00833	0.02905	-0.65448	-0.65235
-0.60278	-0.64694	-0.63618	-0.65376	-0.65398	-0.60868	-0.64802	-0.63423	-0.63717	-0.66789
-0.62335	-0.65037	-0.62322	-0.62754	-0.63513	-0.55865	-0.67933	-0.63656	-0.64782	0.32584
0.72857	0.70881	0.66910	0.07850	-0.25754	-0.21108	-0.38509	0.00463	-0.07371	0.01932
-0.02312	-0.05857	-0.13186	-0.03463	0.07346					

ROW 11

0.55705	0.22901	-0.02339	-0.64101	-0.60575	-0.57364	-0.65646	-0.67333	0.53968	0.59585
1.00000	0.64523	0.42617	-0.70640	-0.69642	-0.62714	-0.70560	-0.74261	-0.09968	-0.13034
-0.18075	-0.15605	-0.05903	-0.05889	0.02960	-0.03636	-0.03523	-0.05717	-0.11152	-0.15592
-0.09695	-0.10380	-0.06268	-0.02548	0.10982	-0.04733	-0.09613	-0.10745	-0.63950	-0.60765
-0.58298	-0.64455	-0.69457	-0.63444	-0.60834	-0.58611	-0.64457	-0.69226	-0.60260	-0.61199
-0.59195	-0.63616	-0.66177	-0.65626	-0.59838	-0.59826	-0.67606	-0.71230	-0.66990	0.24527
0.79391	0.66358	0.54457	0.01317	-0.29171	-0.31566	-0.24511	0.03371	0.22428	0.25524
0.24212	0.22209	0.14819	-0.02351	0.02986					

ROW 12

0.76413	-0.28370	0.08438	-0.63988	-0.60617	-0.55488	-0.62272	-0.42631	0.62363	0.77726
0.64523	1.00000	0.66575	-0.68359	-0.68327	-0.55637	-0.62636	-0.59113	-0.13564	-0.13945
-0.23790	-0.20624	-0.01288	-0.10037	0.00485	0.04294	-0.16044	-0.12210	-0.15838	-0.22741
-0.21071	-0.19112	-0.08366	-0.01257	0.34477	0.05052	-0.07629	-0.04795	-0.63965	-0.61014
-0.57946	-0.62095	-0.65115	-0.63767	-0.61146	-0.58458	-0.62180	-0.64930	-0.61375	-0.62848
-0.59601	-0.61712	-0.63198	-0.60366	-0.66362	-0.58706	-0.65981	-0.55912	-0.61491	0.22080
0.63577	0.86440	0.75735	-0.00583	-0.33689	-0.22130	-0.43183	0.15870	-0.31895	-0.19372
-0.26478	-0.31316	-0.29443	-0.11611	-0.02837					

ROW 13

0.52333	-0.25910	-0.14985	-0.41260	-0.38712	-0.34668	-0.34836	-0.28041	0.41213	0.62915
0.42617	0.66575	1.00000	-0.46749	-0.47426	-0.40128	-0.40763	-0.45634	-0.05052	-0.04252
-0.07987	-0.03340	0.04576	-0.00137	0.05656	-0.09943	0.02518	0.04111	-0.06023	-0.00540
0.04860	0.02593	0.00586	0.05448	0.06164	-0.18290	-0.07657	0.16306	-0.40595	-0.38752
-0.35324	-0.34601	-0.41864	-0.40209	-0.38663	-0.35196	-0.34704	-0.41648	-0.36266	-0.38865
-0.34325	-0.34889	-0.38939	-0.38737	-0.43004	-0.30278	-0.33623	-0.40649	-0.39151	0.19421
0.50167	0.59614	0.76949	-0.07076	-0.15460	-0.24629	-0.42807	0.18401	-0.28211	-0.23365
-0.24098	-0.26152	-0.29675	0.02816	0.06381					

ROW 14

-0.85388	-0.23705	-0.36619	0.80462	0.79416	0.76641	0.81253	0.67208	-0.60961	-0.76925
-0.70640	-0.68359	-0.46749	1.00000	0.98572	0.92512	0.97109	0.92575	-0.00687	0.07592
0.15302	0.07767	-0.09583	-0.01460	-0.03375	0.00948	0.04931	-0.06507	0.03040	0.18330
0.13195	0.09483	-0.09077	-0.11870	-0.15117	-0.01419	-0.00433	-0.00144	0.80451	0.80292
0.80073	0.81733	0.77526	0.80306	0.80449	0.80528	0.81794	0.77373	0.77586	0.81918
0.82081	0.82194	0.75585	0.77641	0.75850	0.77798	0.78388	0.62028	0.80140	-0.15801
-0.66888	-0.59244	-0.53399	-0.09730	0.25667	0.26174	0.24187	-0.15646	-0.20515	-0.25695
-0.24054	-0.20890	-0.13891	-0.14774	-0.18706					

ROW 15

-0.82021	-0.21758	-0.30242	0.79874	0.81688	0.81083	0.81881	0.67016	-0.55981	-0.75264
-0.68642	-0.68327	-0.47426	0.98572	1.00000	0.96311	0.97500	0.92369	0.00002	0.09298
0.17400	0.09025	-0.09025	-0.01466	-0.00132	0.09385	0.07550	-0.05936	0.02487	0.17901
0.13872	0.08956	-0.08913	-0.10363	-0.09571	0.06625	0.07825	0.01085	0.79332	0.81782
0.83338	0.82459	0.78144	0.79027	0.81786	0.83522	0.82502	0.77955	0.75883	0.82635
0.84260	0.82666	0.75756	0.73430	0.77726	0.79160	0.78650	0.61069	0.75783	-0.11736
-0.63946	-0.60090	-0.55055	-0.09485	0.23644	0.27787	0.25957	-0.12243	-0.18113	-0.23843
-0.21789	-0.18518	-0.11821	-0.14775	-0.17288					

ROW 16

-0.68580	-0.32362	-0.23184	0.74752	0.79307	0.83246	0.76627	0.63719	-0.44232	-0.63288
-0.62214	-0.55637	-0.40128	0.92512	0.96311	1.00000	0.93512	0.87988	0.00601	0.11162
0.18181	0.05395	-0.08197	-0.00083	0.07265	0.27214	0.10500	-0.05175	-0.00087	0.15539
0.12171	0.05451	-0.10410	-0.05847	0.00348	0.23978	0.24150	0.05324	0.73172	0.78014
0.82868	0.77252	0.73150	0.72658	0.77729	0.82467	0.77274	0.73022	0.69672	0.77930
0.81795	0.78073	0.71268	0.67441	0.73845	0.75395	0.71107	0.55347	0.69527	-0.09240
-0.57219	-0.49986	-0.46904	-0.07352	0.21279	0.30844	0.19938	-0.11537	-0.28175	-0.33861
-0.31733	-0.28880	-0.22357	-0.16128	-0.14688					

ROW 17

-0.78612	-0.28518	-0.30022	0.76870	0.77870	0.75933	0.82568	0.69977	-0.53952	-0.71396
-0.70560	-0.62636	-0.40763	0.97109	0.97500	0.93512	1.00000	0.94516	-0.02691	0.06612
0.13095	0.06405	-0.08895	-0.04167	-0.04122	-0.01335	0.02263	-0.09039	0.00722	0.14379
0.10013	0.05312	-0.10194	-0.12623	-0.10578	-0.05430	0.01913	0.00384	0.77057	0.79220
0.80151	0.83327	0.76889	0.76953	0.79434	0.80702	0.83363	0.76770	0.74516	0.80832
0.82625	0.83820	0.74855	0.71525	0.71990	0.78020	0.78506	0.61593	0.73794	-0.13115
-0.63147	-0.54117	-0.50715	-0.09598	0.22124	0.28113	0.19074	-0.07611	-0.25522	-0.29892
-0.28322	-0.25706	-0.19661	-0.17863	-0.19521					

ROW 18

-0.69543	-0.36837	-0.18886	0.70889	0.71593	0.68912	0.75836	0.71483	-0.50836	-0.74134
-0.74261	-0.59113	-0.45634	0.92575	0.92369	0.87988	0.94516	1.00000	-0.06926	0.02381
0.07425	0.01530	-0.11952	-0.10829	-0.09711	-0.03505	-0.05913	-0.15071	-0.02053	0.07946
0.02157	-0.00095	-0.11827	-0.18837	-0.09726	-0.02156	0.05379	-0.07492	0.70639	0.72685
0.72546	0.76817	0.74558	0.70307	0.72769	0.72927	0.76853	0.74341	0.67249	0.73639
0.74244	0.77114	0.71953	0.67584	0.64149	0.67601	0.74995	0.68708	0.69839	-0.16773
-0.67757	-0.56768	-0.53595	-0.11147	0.14567	0.23757	0.25475	-0.04547	-0.34231	-0.38000
-0.37304	-0.34551	-0.29027	-0.22067	-0.25569					

ROW 19

-0.03520	0.24253	0.12289	0.58093	0.52732	0.46387	0.48224	0.46454	-0.05148	-0.04140
-0.09968	-0.13564	-0.05052	-0.00687	0.00002	0.00601	-0.02691	-0.06926	1.00000	0.92824
0.97573	0.90767	0.92046	0.88677	0.69846	0.30705	0.64820	0.94311	0.97238	0.83180
0.71255	0.76797	0.92428	0.80762	0.27850	0.17793	0.24532	0.76914	0.57789	0.52213
0.44953	0.46602	0.53807	0.57904	0.52120	0.44886	0.46604	0.54336	0.60801	0.52153
0.44585	0.47054	0.58534	0.48593	0.49886	0.38109	0.39857	0.41890	0.43970	-0.17077
-0.08677	-0.12688	0.06420	0.74071	0.41286	0.13678	0.21623	-0.17397	0.28290	0.25010
0.25901	0.28035	0.27661	0.78654	0.79765					

ROW 20

-0.11612	0.14543	-0.00384	0.60799	0.64055	0.59069	0.57930	0.53524	-0.07200	-0.11399
-0.13034	-0.13945	-0.04252	0.07592	0.09298	0.11162	0.06612	0.02381	0.92824	1.00000
0.95733	0.94742	0.90932	0.83514	0.76817	0.37161	0.64287	0.79994	0.91795	0.89602
0.79759	0.82812	0.90070	0.71842	0.43165	0.25866	0.25011	0.72864	0.60237	0.63129
0.57181	0.56538	0.57652	0.60282	0.62885	0.56917	0.56506	0.58154	0.63400	0.61753
0.56026	0.56703	0.62449	0.46860	0.61604	0.50035	0.47865	0.40836	0.43101	-0.04185
-0.09615	-0.12933	0.03868	0.60472	0.32665	0.12881	0.25314	-0.12137	0.18156	0.15142
0.16305	0.17805	0.18024	0.74843	0.71479					

ROW 21

-0.23228	0.19345	-0.11367	0.63588	0.67517	0.66118	0.63752	0.53983	-0.19021	-0.17530
-0.18075	-0.23790	-0.07987	0.15302	0.17420	0.18181	0.13095	0.07425	0.87573	0.95733
1.00000	0.96373	0.87104	0.77599	0.70000	0.39805	0.65166	0.77511	0.87677	0.88446
0.83217	0.84755	0.87971	0.62349	0.29737	0.27394	0.23100	0.70061	0.63239	0.66272
0.63838	0.62145	0.60760	0.63352	0.66053	0.62553	0.62131	0.61240	0.66931	0.65987
0.62804	0.62668	0.65872	0.50988	0.65512	0.57817	0.57313	0.41009	0.47578	-0.06009
-0.16744	-0.20202	-0.04572	0.55734	0.35150	0.23167	0.29665	-0.11859	0.22551	0.20477
0.21046	0.22171	0.23762	0.72056	0.66083					

ROW 22

-0.19450	0.22548	-0.09866	0.59605	0.69897	0.54840	0.60636	0.53689	-0.14681	-0.13919
-0.15605	-0.20624	-0.03340	0.07767	0.08025	0.05395	0.06405	0.01530	0.90767	0.94742
0.96373	1.00000	0.92859	0.80206	0.65056	0.19577	0.65783	0.82058	0.92632	0.89890
0.82549	0.87694	0.94614	0.64741	0.16757	0.07342	0.13773	0.74564	0.60021	0.60104
0.54749	0.59087	0.58851	0.60388	0.60171	0.54989	0.59082	0.59333	0.64521	0.60841
0.55684	0.59383	0.64202	0.46349	0.58221	0.51879	0.56464	0.42126	0.42668	-0.04844
-0.12078	-0.14874	0.00682	0.58410	0.30158	0.15928	0.27452	-0.12452	0.25115	0.24169
0.24487	0.25273	0.25217	0.76362	0.71214					

ROW 23

0.02319	0.17920	0.09952	0.46604	0.44814	0.40055	0.44601	0.52643	0.03754	0.04785
-0.05903	-0.01288	0.04576	-0.09583	-0.09005	-0.08197	-0.08885	-0.11952	0.92046	0.90932
0.87104	0.92859	1.00000	0.80193	0.66163	0.24398	0.61736	0.84025	0.92042	0.80811
0.71131	0.78176	0.95360	0.71699	0.29530	0.12250	0.19057	0.79159	0.46661	0.44850
0.38922	0.43049	0.48563	0.46886	0.44864	0.38943	0.43002	0.49006	0.50080	0.44617
0.38938	0.42987	0.52755	0.32557	0.40880	0.34355	0.36179	0.35808	0.28032	-0.03242
-0.00105	0.01827	0.19423	0.66728	0.25093	0.10481	0.16757	-0.15776	0.20222	0.19835
0.20221	0.19994	0.19352	0.77170	0.77389					

ROW 24

-0.06172	0.23909	0.04655	0.50641	0.45708	0.39953	0.40807	0.36870	-0.06043	-0.05476
-0.05889	-0.10037	-0.00137	-0.01460	-0.01466	-0.00083	-0.04167	-0.10829	0.88677	0.83514
0.77599	0.80206	0.80193	1.00000	0.85973	0.35732	0.80851	0.93515	0.81238	0.87721
0.83568	0.86186	0.81086	0.93280	0.34587	0.17953	0.26828	0.86270	0.50693	0.45460
0.38770	0.38766	0.42320	0.51033	0.45432	0.38800	0.38776	0.42795	0.53998	0.45548
0.38742	0.39562	0.46739	0.44554	0.41326	0.31714	0.30342	0.29268	0.42417	-0.09168
-0.10531	-0.07713	0.09520	0.44977	0.32811	0.16669	0.19426	-0.18066	0.26775	0.25959
0.27408	0.27408	0.24707	0.88887	0.89985					

ROW 25

0.01349	0.14444	0.12178	0.38645	0.43394	0.42843	0.32869	0.30402	0.02159	-0.05921
-0.02900	-0.00485	0.05656	-0.03375	-0.00132	0.07265	-0.04122	-0.09711	0.69846	0.76812
0.70000	0.65056	0.66163	0.85973	1.00000	0.61447	0.81293	0.84370	0.59375	0.77985
0.81897	0.78877	0.62009	0.86452	0.62705	0.44971	0.45577	0.77377	0.37590	0.41489
0.38928	0.31125	0.32247	0.37469	0.41028	0.38185	0.31077	0.32542	0.39136	0.38570
0.35556	0.31112	0.34717	0.27791	0.39745	0.29027	0.20359	0.18260	0.26882	0.03753
-0.07376	-0.02707	0.10949	0.24362	0.26582	0.13871	0.13247	-0.01542	0.16714	0.14626
0.17255	0.16739	0.14048	0.82813	0.79748					

ROW 26

0.12595	-0.02390	0.26972	0.18662	0.28072	0.41236	0.09705	0.11080	0.08602	0.04568
-0.03636	0.04294	-0.09943	0.00948	0.09385	0.27214	-0.01335	-0.03505	0.30705	0.37161
0.38805	0.19577	0.24398	0.35732	0.61447	1.00000	0.42659	0.34538	0.16826	0.24844
0.31191	0.23756	0.17711	0.43912	0.69254	0.94982	0.71880	0.34034	0.15163	0.22369
0.31005	0.08610	0.13811	0.14051	0.21149	0.28676	0.08522	0.13823	0.12089	0.17142
0.21577	0.08699	0.13039	0.10616	0.27192	0.15660	-0.00329	0.00631	0.09853	0.00865
-0.08366	-0.06157	0.01780	0.15152	0.18715	0.26081	0.11202	-0.07595	0.00818	-0.01030
-0.00374	-0.01768	0.00308	0.30819	0.33374					

ROW 27

-0.17867	0.26947	-0.04140	0.43020	0.42885	0.44183	0.39245	0.29151	-0.07218	-0.14085
-0.03523	-0.16044	0.02518	0.04931	0.07550	0.10500	0.02263	-0.05913	0.64820	0.64287
0.65166	0.65783	0.61736	0.80851	0.81293	0.42659	1.00000	0.87198	0.55922	0.73869
0.81426	0.81509	0.59554	0.77944	0.23177	0.22452	0.47423	0.81874	0.42618	0.42172
0.42848	0.37805	0.37773	0.42769	0.42049	0.42653	0.37774	0.37969	0.43693	0.41219
0.41411	0.36894	0.39172	0.30939	0.38714	0.38753	0.34647	0.18612	0.30463	0.04881
-0.10247	-0.07625	0.02833	0.18315	0.16709	0.12852	0.20158	-0.12374	0.28727	0.27642
0.31411	0.29739	0.27511	0.81736	0.77880					

ROW 28

-0.06391	0.29011	0.06446	0.44402	0.40503	0.37034	0.38346	0.37053	-0.03347	-0.03635
-0.05717	-0.12210	0.04111	-0.06507	-0.05936	-0.05175	-0.09039	-0.15071	0.84311	0.79994
0.77511	0.82058	0.84025	0.93515	0.84370	0.34538	0.87198	1.00000	0.78099	0.86320
0.86229	0.89422	0.83058	0.89056	0.26092	0.16233	0.31763	0.91370	0.44509	0.40318
0.35829	0.36610	0.42240	0.44798	0.40312	0.35840	0.36607	0.42590	0.47511	0.40536
0.35614	0.36874	0.45669	0.33867	0.37455	0.31544	0.32560	0.29802	0.31740	-0.01702
-0.07795	-0.06086	0.12638	0.40901	0.26809	0.11569	0.19392	-0.13137	0.31610	0.30276
0.32630	0.32275	0.30837	0.92941	0.92635					

ROW 29

-0.09574	0.23277	0.03743	0.59633	0.54170	0.46075	0.52095	0.49438	-0.08937	-0.08045
-0.11152	-0.15838	-0.06023	0.03040	0.02487	-0.00087	0.00722	-0.02053	0.97238	0.91795
0.87677	0.92632	0.92042	0.81238	0.59375	0.16826	0.55922	0.78099	1.00000	0.83312
0.69025	0.76096	0.94331	0.69015	0.17194	0.06032	0.10881	0.70048	0.59912	0.54527
0.46055	0.50746	0.57197	0.60203	0.54604	0.46308	0.50764	0.57721	0.63489	0.55121
0.46972	0.51093	0.62146	0.49266	0.50103	0.40884	0.46107	0.46599	0.44573	-0.16573
-0.08296	-0.12994	0.04645	0.73355	0.36830	0.06799	0.22883	-0.16229	0.27193	0.23784
0.25215	0.27071	0.27419	0.72920	0.71850					

ROW 30

-0.26778	0.17018	-0.17256	0.63564	0.64189	0.57737	0.61076	0.51562	-0.16757	-0.20256
-0.15592	-0.22741	-0.00540	0.18330	0.17901	0.15539	0.14379	0.07946	0.83180	0.89602
0.88446	0.89890	0.80811	0.87721	0.77985	0.24844	0.73869	0.86320	0.83312	1.00000
0.93887	0.95276	0.84802	0.74176	0.22993	0.09943	0.13666	0.79444	0.63874	0.64034
0.57529	0.59526	0.58800	0.64317	0.64044	0.57741	0.59541	0.59148	0.67624	0.64555
0.58418	0.60124	0.63490	0.50707	0.60123	0.52342	0.54069	0.40930	0.49229	0.03409
-0.12534	-0.16005	0.02855	0.35338	0.26665	0.11187	0.26830	-0.16409	0.19623	0.17634
0.18900	0.20498	0.19222	0.80689	0.76644					

ROW 31

-0.26198	0.26296	-0.18498	0.52519	0.55521	0.52716	0.53678	0.41256	-0.18105	-0.17991
-0.09695	-0.21071	0.04860	0.13195	0.13872	0.12121	0.10013	0.02157	0.71255	0.79759
0.83217	0.82549	0.71131	0.83568	0.81897	0.31191	0.81426	0.86229	0.69025	0.93887
1.00000	0.97595	0.74748	0.71341	0.21437	0.13546	0.17569	0.78957	0.52956	0.55158
0.52247	0.51980	0.48706	0.53421	0.55153	0.52380	0.51980	0.48464	0.56818	0.55545
0.52702	0.52365	0.52265	0.40546	0.51648	0.47961	0.48098	0.28775	0.39995	0.08406
-0.08518	-0.13096	0.03086	0.20668	0.24636	0.14546	0.26850	-0.07515	0.27022	0.27022
0.27913	0.28127	0.25728	0.82771	0.74735					

ROW 32

-0.24657	0.25434	-0.18083	0.53182	0.53926	0.49294	0.53214	0.43534	-0.15641	-0.18631
-0.10380	-0.19112	0.02593	0.09483	0.08956	0.05451	0.05312	-0.00095	0.76797	0.82812
0.84755	0.87694	0.78176	0.86186	0.78877	0.23756	0.81509	0.89422	0.76096	0.95276
0.97595	1.00000	0.82560	0.72235	0.16908	0.07673	0.13408	0.81310	0.53852	0.54124
0.49300	0.51399	0.49996	0.54350	0.54213	0.49584	0.51399	0.50266	0.57700	0.54528
0.50163	0.51316	0.53971	0.40772	0.49651	0.45522	0.49671	0.33145	0.39712	0.05730
-0.09573	-0.12337	0.04598	0.27529	0.22301	0.11463	0.30729	-0.10013	0.26800	0.26983
0.27778	0.28014	0.25812	0.85358	0.77738					

ROW 33

-0.00959	0.22892	0.05919	0.46968	0.44297	0.38526	0.44477	0.45844	0.02578	0.00105
-0.06268	-0.08366	0.00586	-0.09077	-0.08913	-0.10410	-0.10194	-0.11827	0.92428	0.90070
0.87971	0.94614	0.95360	0.81086	0.62009	0.17711	0.59554	0.83058	0.94331	0.84802
0.74748	0.82560	1.00000	0.69545	0.17344	0.08659	0.13010	0.76111	0.47334	0.44325
0.37362	0.42851	0.49311	0.47649	0.44363	0.37449	0.42829	0.49744	0.51378	0.44781
0.37711	0.43073	0.54314	0.34420	0.40658	0.32090	0.40870	0.40987	0.30098	-0.03426
-0.01020	-0.05855	0.13983	0.65430	0.26416	0.09199	0.27426	-0.18679	0.25685	0.25127
0.25320	0.26114	0.24690	0.79236	0.78205					

ROW 34

0.09455	0.22465	0.26420	0.38093	0.32689	0.28483	0.25851	0.27920	0.06367	0.07057
-0.02548	-0.01257	0.05448	-0.11870	-0.10363	-0.05847	-0.12623	-0.18837	0.80762	0.71842
0.62349	0.64741	0.71699	0.93280	0.86452	0.43912	0.77944	0.89056	0.69015	0.74176
0.71341	0.72235	0.69545	1.00000	0.42658	0.26953	0.39716	0.84156	0.37350	0.31602
0.25948	0.24004	0.31835	0.37347	0.31393	0.25603	0.23969	0.32162	0.38402	0.30376
0.24272	0.24116	0.34216	0.32384	0.30456	0.18116	0.14841	0.21335	0.30492	-0.03481
-0.04374	-0.01263	0.15048	0.39494	0.33794	0.18413	0.09793	-0.19044	0.25018	0.24753
0.26165	0.25631	0.71086	0.86320	0.92794					

ROW 35

0.32656	-0.25972	0.26346	0.04240	0.16994	0.21343	0.00556	0.11987	0.31456	0.19420
0.10982	0.34477	0.08164	-0.15117	-0.09571	0.08348	-0.10578	-0.09726	0.27850	0.43165
0.28737	0.16757	0.29530	0.34587	0.62705	0.69254	0.23177	0.26092	0.17194	0.22993
0.21437	0.16908	0.17344	0.42658	1.00000	0.66832	0.49846	0.29782	0.01334	0.13768
0.15102	0.00372	0.01787	0.00510	0.12817	0.13434	0.00246	0.02013	-0.00118	0.07337
0.08288	0.00390	0.02121	-0.02473	0.13534	0.03377	-0.18257	-0.03963	-0.03521	0.13389
0.12468	0.22684	0.24442	0.15394	0.03535	0.07066	-0.05812	0.01524	-0.23810	-0.23702
-0.24726	-0.25446	-0.26838	0.22705	0.30243					

ROW 36

0.17501	-0.10130	0.31710	0.09222	0.19703	0.32909	-0.00217	0.04250	0.12778	0.03140
-0.04733	0.05052	-0.18290	-0.01419	0.06625	0.23978	-0.05430	-0.02156	0.17793	0.25866
0.27394	0.07342	0.12250	0.17953	0.44971	0.94982	0.22452	0.16233	0.06032	0.09943
0.13546	0.07673	0.08659	0.26953	0.66832	1.00000	0.68081	0.14806	0.05243	0.13394
0.21466	-0.01151	0.07436	0.03867	0.12033	0.18849	-0.01249	0.07353	0.01183	0.07608
0.10955	-0.01120	0.06329	0.04367	0.20943	0.05179	-0.07309	0.01616	0.03644	0.01771
-0.08300	-0.08732	-0.01385	0.12722	0.12304	0.22550	0.13959	-0.09964	-0.07266	-0.09494
-0.09545	-0.10163	-0.07107	0.15428	0.18943					

ROW 37

0.19197	-0.13910	0.33178	0.13418	0.19221	0.29320	0.08681	0.15117	0.19169	-0.00833
-0.09613	-0.02629	-0.07657	-0.00433	0.07825	0.24160	0.01913	0.05379	0.24532	0.25011
0.23100	0.13773	0.19057	0.26828	0.45577	0.71880	0.47423	0.31763	0.10881	0.13666
0.17569	0.13408	0.13010	0.39716	0.49846	0.68081	1.00000	0.33441	0.09576	0.14803
0.21798	0.08362	0.13763	0.08463	0.13785	0.19984	0.08264	0.13804	0.06718	0.11311
0.14579	0.08920	0.13364	0.04927	0.19461	0.14033	0.06800	0.08889	0.04149	0.02322
-0.13692	-0.10666	-0.00834	0.12099	0.02567	0.20912	0.11862	-0.14899	-0.10257	-0.11624
-0.10453	-0.11761	-0.12340	0.23285	0.31514					

ROW 38

-0.03912	0.13119	0.01001	0.45590	0.42199	0.41564	0.42080	0.42454	0.03886	0.02905
-0.10745	-0.04795	0.16306	-0.00144	0.01085	0.05324	0.00384	-0.07492	0.76914	0.72864
0.70061	0.74564	0.79159	0.86270	0.77377	0.34034	0.81874	0.91370	0.70048	0.79444
0.78957	0.81310	0.76111	0.84156	0.29782	0.14806	0.33441	1.00000	0.45491	0.41789
0.40044	0.39914	0.44954	0.45701	0.41774	0.40032	0.39865	0.45146	0.47246	0.41312
0.39774	0.39497	0.46560	0.31876	0.35757	0.37599	0.35394	0.28726	0.30119	0.01192
-0.04164	-0.01039	0.19595	0.36689	0.25213	0.14789	0.18685	-0.17310	0.14902	0.14593
0.17218	0.16079	0.14092	0.80719	0.88609					

ROW 39

-0.73130	-0.02381	-0.23737	0.99778	0.95561	0.89096	0.95223	0.82327	-0.53350	-0.65448
-0.63950	-0.63965	-0.40595	0.80451	0.79332	0.73172	0.77057	0.70639	0.57789	0.60237
0.63239	0.60021	0.46661	0.50693	0.37590	0.15163	0.42618	0.44509	0.59912	0.63874
0.52956	0.53852	0.47334	0.37350	0.01334	0.05243	0.09576	0.45491	1.00000	0.96521
0.91978	0.94639	0.95172	0.99976	0.96682	0.92477	0.94673	0.95299	0.98872	0.97328
0.93664	0.94259	0.95324	0.90382	0.90356	0.87520	0.88177	0.74138	0.89819	-0.20957
-0.58435	-0.56303	-0.39829	0.33528	0.44525	0.26736	0.33097	-0.21400	0.02420	-0.03326
-0.00918	0.02181	0.07538	0.34529	0.31336					

ROW 40

-0.71702	-0.06331	-0.24949	0.96838	0.99587	0.95443	0.97440	0.83329	-0.47280	-0.65235
-0.60765	-0.61014	-0.38752	0.80292	0.81782	0.78014	0.79220	0.72685	0.52213	0.63129
0.66272	0.60104	0.44850	0.45460	0.41489	0.22369	0.42172	0.40318	0.54527	0.64034
0.55158	0.54124	0.44325	0.31602	0.13768	0.13394	0.14803	0.41789	0.96521	1.00000
0.97596	0.97308	0.94254	0.96372	0.99987	0.97824	0.97301	0.94333	0.94821	0.99260
0.98064	0.96259	0.93786	0.82115	0.94390	0.92026	0.89071	0.69677	0.81890	-0.08847
-0.52837	-0.53622	-0.40287	0.25160	0.36087	0.25463	0.34886	-0.15534	-0.01637	-0.07211
-0.05167	-0.01907	0.03169	0.30105	0.26025					

ROW 41

-0.69238	-0.10025	-0.26598	0.92689	0.97778	0.98573	0.95618	0.79461	-0.45258	-0.60278
-0.58298	-0.57946	-0.35324	0.80073	0.83338	0.82868	0.80151	0.72546	0.44953	0.57181
0.63838	0.54749	0.38922	0.38770	0.38928	0.31005	0.42848	0.35829	0.46055	0.57529
0.52247	0.49300	0.37362	0.25948	0.15102	0.21466	0.21798	0.40044	0.91978	0.97596
1.00000	0.95758	0.91058	0.91638	0.97456	0.99957	0.95725	0.91081	0.89506	0.96148
0.99297	0.94191	0.89640	0.76542	0.91474	0.94106	0.87871	0.62665	0.76618	-0.04724
-0.49460	-0.50798	-0.39999	0.19019	0.33038	0.29746	0.32842	-0.13014	-0.05498	-0.10062
-0.08348	-0.05756	-0.00342	0.23218	0.20889					

ROW 42

-0.73414	-0.09525	-0.27964	0.94371	0.95889	0.91876	0.99769	0.86175	-0.49831	-0.64694
-0.64455	-0.62095	-0.34601	0.81733	0.82459	0.77252	0.83327	0.76817	0.46602	0.56538
0.62145	0.59087	0.43049	0.38766	0.31125	0.08610	0.37805	0.36610	0.50746	0.59526
0.51980	0.51399	0.42851	0.24004	0.00372	-0.01151	0.08362	0.39914	0.94639	0.97308
0.95758	1.00000	0.95060	0.94635	0.97509	0.96347	0.99999	0.95158	0.93810	0.97974
0.97872	0.99288	0.94908	0.80661	0.89891	0.92404	0.94064	0.71676	0.80535	-0.08723
-0.54524	-0.51762	-0.40527	0.22585	0.32107	0.27855	0.31543	-0.13547	-0.05754	-0.09565
-0.08317	-0.05712	-0.01072	0.25550	0.21659					

ROW 43

-0.66583	-0.07962	-0.09377	0.95560	0.93526	0.88592	0.94915	0.88219	-0.44120	-0.63618
-0.69457	-0.65115	-0.41864	0.77526	0.78144	0.73150	0.76889	0.74558	0.53807	0.57652
0.60760	0.58851	0.48563	0.42320	0.32247	0.13811	0.37773	0.42240	0.57197	0.58800
0.48206	0.49996	0.49311	0.31835	0.01787	0.07436	0.13763	0.44954	0.95172	0.94254
0.91058	0.95060	1.00000	0.94858	0.94312	0.91357	0.95057	0.99992	0.92534	0.94235
0.91883	0.94028	0.98654	0.82534	0.87590	0.84717	0.89867	0.83877	0.81690	-0.12600
-0.55650	-0.55672	-0.39133	0.34084	0.37642	0.25178	0.36379	-0.19729	-0.03621	-0.09383
-0.07020	-0.03808	0.02077	0.31906	0.30990					

ROW 44

-0.73498	-0.01998	-0.24777	0.99643	0.95254	0.88584	0.95246	0.82034	-0.53779	-0.65376
-0.63444	-0.63767	-0.40209	0.80306	0.79027	0.72658	0.76953	0.70307	0.57904	0.60282
0.63352	0.60388	0.46886	0.51033	0.37469	0.14051	0.42769	0.44798	0.60203	0.64317
0.53421	0.54350	0.47649	0.37347	0.00510	0.03867	0.08463	0.45701	0.99976	0.96322
0.91638	0.94635	0.94858	1.00000	0.96508	0.92182	0.94673	0.94997	0.99099	0.97322
0.93534	0.94371	0.95210	0.90412	0.89955	0.87449	0.88276	0.73847	0.89856	-0.21376
-0.58337	-0.55925	-0.39571	0.33432	0.44387	0.26724	0.32871	-0.21168	0.02795	-0.02894
-0.00480	0.02575	0.07904	0.34920	0.31518					

ROW 45

-0.72192	-0.06070	-0.25544	0.96912	0.99444	0.95095	0.97638	0.83460	-0.47645	-0.65398
-0.60834	-0.61146	-0.38663	0.80449	0.81786	0.77729	0.79434	0.72769	0.52120	0.62885
0.66053	0.60171	0.44864	0.45432	0.41028	0.21149	0.42049	0.40312	0.54604	0.64044
0.55153	0.54213	0.44363	0.31393	0.12817	0.12033	0.13785	0.41774	0.96682	0.99987
0.97456	0.97509	0.94312	0.96508	1.00000	0.97728	0.97503	0.94393	0.95062	0.99358
0.98096	0.96469	0.93870	0.82272	0.94181	0.92157	0.89312	0.69713	0.82059	-0.09061
-0.52910	-0.53486	-0.40255	0.25049	0.36176	0.25398	0.34685	-0.15487	-0.01414	-0.06914
-0.04892	-0.01666	0.03406	0.30114	0.25953					

ROW 46

-0.70220	-0.09653	-0.27770	0.93035	0.97780	0.98228	0.96199	0.79803	-0.46084	-0.60868
-0.58611	-0.58458	-0.35196	0.80528	0.83522	0.82467	0.80702	0.72927	0.44886	0.56917
0.63553	0.54989	0.38943	0.38800	0.38185	0.28676	0.42653	0.35840	0.46308	0.57741
0.52380	0.49584	0.37449	0.25603	0.13434	0.18849	0.19984	0.40032	0.92477	0.97824
0.99957	0.96347	0.91357	0.92182	0.97728	1.00000	0.96317	0.91384	0.90132	0.96546
0.99578	0.94769	0.89962	0.76953	0.91377	0.94604	0.88561	0.62940	0.77051	-0.05025
-0.49705	-0.50912	-0.40177	0.18790	0.33103	0.29396	0.32654	-0.12662	-0.05177	-0.09669
-0.07961	-0.05380	0.00004	0.23199	0.20688					

ROW 47

-0.73523	-0.09451	-0.28032	0.94399	0.95876	0.91834	0.99769	0.86113	-0.49985	-0.64802
-0.64457	-0.62180	-0.34704	0.81794	0.82502	0.77274	0.83363	0.76853	0.46604	0.56506
0.62131	0.59087	0.43002	0.38776	0.31077	0.08522	0.37774	0.36607	0.50764	0.59541
0.51980	0.51399	0.42829	0.23969	0.00246	-0.01249	0.08264	0.39865	0.94673	0.97301
0.95725	0.99999	0.95057	0.94673	0.97503	0.96317	1.00000	0.95157	0.93874	0.98001
0.97861	0.99321	0.94939	0.80761	0.89891	0.92371	0.94089	0.71741	0.80636	-0.08884
-0.54617	-0.51806	-0.40627	0.22616	0.32180	0.27888	0.31527	-0.13525	-0.05672	-0.09501
-0.08245	-0.05638	-0.00983	0.25558	0.21654					

ROW 48

-0.66454	-0.08110	-0.09633	0.95677	0.93596	0.88609	0.95012	0.88225	-0.44158	-0.63423
-0.69226	-0.64930	-0.41648	0.77373	0.77955	0.73022	0.76770	0.74341	0.54336	0.58154
0.61240	0.59333	0.49006	0.42795	0.32542	0.13823	0.37969	0.42590	0.57721	0.59148
0.48464	0.50266	0.49744	0.32162	0.02013	0.07353	0.13804	0.45146	0.95299	0.94333
0.91081	0.95158	0.99992	0.94997	0.94393	0.91384	0.95157	1.00000	0.92798	0.94385
0.91950	0.94214	0.98813	0.82861	0.87672	0.84729	0.89884	0.83880	0.81976	-0.12955
-0.55688	-0.55459	-0.38895	0.34693	0.37833	0.25352	0.36076	-0.19702	-0.03723	-0.09500
-0.07131	-0.03928	0.01999	0.32254	0.31310					

ROW 49

-0.71980	-0.02390	-0.29014	0.98225	0.93607	0.86353	0.94596	0.79974	-0.54884	-0.63717
-0.60260	-0.61375	-0.36266	0.77586	0.75883	0.69672	0.74516	0.67249	0.60801	0.63400
0.66931	0.64521	0.50080	0.53998	0.39136	0.12089	0.43693	0.47511	0.63489	0.67624
0.56818	0.57700	0.51378	0.38402	-0.00118	0.01183	0.06718	0.47246	0.98872	0.94821
0.89506	0.93810	0.92534	0.99099	0.95062	0.90132	0.93874	0.92798	1.00000	0.96985
0.92112	0.94739	0.94939	0.90818	0.88508	0.85907	0.88251	0.72738	0.90017	-0.25906
-0.58110	-0.53484	-0.36732	0.36347	0.45325	0.27813	0.30454	-0.17993	0.02612	-0.03288
-0.00752	0.02296	0.07715	0.38312	0.33441					

ROW 50

-0.74430	-0.05957	-0.28820	0.97263	0.98470	0.93371	0.98169	0.83057	-0.51121	-0.66789
-0.61199	-0.62848	-0.38865	0.81918	0.82635	0.77930	0.80832	0.73639	0.52153	0.61753
0.65987	0.60841	0.44617	0.45548	0.38570	0.17142	0.41219	0.40536	0.55121	0.64555
0.55545	0.54528	0.44791	0.30376	0.07337	0.07608	0.11311	0.41312	0.97328	0.99260
0.96148	0.97974	0.94235	0.97322	0.99358	0.96546	0.98001	0.94385	0.96985	1.00000
0.97665	0.98071	0.95148	0.84903	0.93575	0.91381	0.90802	0.71181	0.84641	-0.13636
-0.55466	-0.53687	-0.40655	0.26408	0.37781	0.27731	0.33242	-0.15598	-0.01294	-0.06779
-0.04786	-0.01653	0.03715	0.30722	0.26051					

ROW 51

-0.72993	-0.09369	-0.31721	0.93793	0.97449	0.96557	0.97725	0.80627	-0.48753	-0.62335
-0.59195	-0.59601	-0.34325	0.82081	0.84260	0.81795	0.82625	0.74244	0.44585	0.56026
0.62804	0.55684	0.38938	0.38742	0.35556	0.21577	0.41411	0.35614	0.46972	0.58418
0.52702	0.50163	0.37711	0.24272	0.08288	0.10955	0.14579	0.39774	0.93664	0.98064
0.99297	0.97872	0.91883	0.93534	0.98096	0.99578	0.97861	0.91950	0.92112	0.97665
1.00000	0.96741	0.91096	0.78724	0.90891	0.95222	0.90472	0.64094	0.78850	-0.06946
-0.50816	-0.50616	-0.40254	0.18797	0.33398	0.29120	0.31346	-0.11896	-0.05034	-0.09373
-0.07689	-0.05123	0.00229	0.23056	0.20075					

ROW 52

-0.73408	-0.11201	-0.29512	0.93935	0.94908	0.90459	0.99117	0.85105	-0.51267	-0.65037
-0.63616	-0.61712	-0.34889	0.82194	0.82666	0.78073	0.83820	0.77114	0.47054	0.56703
0.62668	0.59383	0.42987	0.39562	0.31112	0.08699	0.36894	0.36874	0.51093	0.60124
0.52365	0.51316	0.43073	0.24116	0.00390	-0.01120	0.08920	0.39497	0.94259	0.96259
0.94191	0.99288	0.94028	0.94371	0.96469	0.94769	0.99321	0.94214	0.94739	0.98071
0.96741	1.00000	0.95472	0.82746	0.89315	0.90304	0.93550	0.72849	0.82510	-0.13031
-0.56405	-0.50504	-0.39823	0.24755	0.33675	0.30490	0.29977	-0.13669	-0.07257	-0.11181
-0.10030	-0.07466	-0.02557	0.26331	0.22307					

ROW 53

-0.64964	-0.09304	-0.13490	0.95556	0.93094	0.87362	0.94933	0.86895	-0.45308	-0.62322
-0.66177	-0.63198	-0.38939	0.75585	0.75756	0.71268	0.74855	0.71953	0.58534	0.62449
0.65872	0.64202	0.52755	0.46739	0.34717	0.13039	0.39172	0.45669	0.62146	0.63490
0.52265	0.53971	0.54314	0.34216	0.02121	0.06329	0.13364	0.46560	0.95324	0.93786
0.89640	0.94908	0.98654	0.95210	0.93870	0.89962	0.94939	0.98813	0.94939	0.95148
0.91096	0.95472	1.00000	0.85122	0.87742	0.82975	0.90220	0.83737	0.83920	-0.17984
-0.56399	-0.53569	-0.36586	0.39117	0.39574	0.27886	0.33998	-0.18235	-0.04673	-0.10969
-0.08390	-0.05099	0.01019	0.36093	0.34065					

ROW 54

-0.70467	-0.09059	-0.23962	0.90281	0.81466	0.74239	0.81189	0.68855	-0.65138	-0.62754
-0.65626	-0.60366	-0.38737	0.77641	0.73430	0.67441	0.71525	0.67584	0.48593	0.46860
0.50988	0.46349	0.32557	0.44554	0.27791	0.10616	0.30939	0.33867	0.49266	0.50707
0.40546	0.40772	0.34420	0.32384	-0.02473	0.04367	0.04927	0.31876	0.90382	0.82115
0.76542	0.80661	0.82534	0.90412	0.82272	0.76953	0.80761	0.82861	0.90818	0.84903
0.78724	0.82746	0.85122	1.00000	0.78177	0.70648	0.74407	0.73658	0.99731	-0.36673
-0.67414	-0.51506	-0.37489	0.34577	0.51999	0.34119	0.18428	-0.28156	-0.05243	-0.08592
-0.08297	-0.05666	-0.00026	0.28373	0.24734					

ROW 55

-0.70044	0.00966	-0.20256	0.91448	0.95245	0.91312	0.90299	0.74646	-0.47661	-0.63533
-0.59838	-0.66362	-0.43004	0.75850	0.77726	0.73845	0.71980	0.64149	0.49886	0.61604
0.65512	0.58221	0.40880	0.41326	0.39745	0.27192	0.38714	0.37455	0.50103	0.60123
0.51648	0.49651	0.40658	0.30456	0.13534	0.20943	0.19461	0.35757	0.90355	0.94390
0.91474	0.89891	0.87590	0.89955	0.94181	0.91377	0.89891	0.87672	0.88508	0.93576
0.90891	0.89315	0.87742	0.78177	1.00000	0.87521	0.83928	0.62179	0.77869	-0.04071
-0.52718	-0.58889	-0.45328	0.24707	0.37202	0.25541	0.32931	-0.21787	0.05482	-0.01241
0.00833	0.04497	0.10168	0.29465	0.24348					

ROW 56

-0.72080	-0.09081	-0.38590	0.87175	0.90997	0.90748	0.92770	0.74116	-0.46655	-0.55865
-0.58826	-0.58706	-0.30278	0.77798	0.79160	0.75395	0.78020	0.67601	0.38109	0.50035
0.57817	0.51879	0.34355	0.31714	0.29027	0.15660	0.38753	0.31544	0.40884	0.52342
0.47961	0.45522	0.32090	0.18116	0.03377	0.05179	0.14033	0.37599	0.87520	0.92026
0.94106	0.92404	0.84717	0.87449	0.92157	0.94604	0.92371	0.84729	0.85907	0.91381
0.95222	0.90304	0.82975	0.70648	0.87521	1.00000	0.88265	0.54842	0.71026	-0.00919
-0.44323	-0.51029	-0.38752	0.11151	0.30876	0.24245	0.28722	-0.08977	-0.04374	-0.09240
-0.07005	-0.04107	0.02058	0.17500	0.14776					

ROW 57

-0.73375	-0.07060	-0.31925	0.87480	0.87793	0.84464	0.94466	0.76254	0.53717	-0.67933
-0.67606	-0.66981	-0.33623	0.78388	0.78650	0.71107	0.78506	0.74995	0.39857	0.47865
0.57313	0.56464	0.36179	0.30342	0.20359	-0.00329	0.34647	0.32560	0.46107	0.54069
0.48098	0.49671	0.40870	0.14841	-0.18257	-0.07309	0.06800	0.35394	0.88177	0.89071
0.87871	0.94064	0.89867	0.88276	0.89312	0.88561	0.94089	0.89894	0.88251	0.90802
0.90472	0.93550	0.90220	0.74407	0.83928	0.88265	1.00000	0.71588	0.74545	-0.12334
-0.60329	-0.61192	-0.47778	0.15453	0.25730	0.25407	0.39881	-0.06665	-0.03308	-0.07420
-0.05746	-0.02737	0.02140	0.23394	0.17281					

ROW 58

-0.51339	-0.14789	0.06845	0.74310	0.69091	0.61001	0.71679	0.71960	-0.39858	-0.63656
-0.71230	-0.55912	-0.40649	0.62028	0.61069	0.55347	0.61593	0.68708	0.41890	0.40836
0.41009	0.42126	0.35808	0.29268	0.18260	0.00631	0.18612	0.29802	0.46599	0.40930
0.28775	0.33145	0.40987	0.21335	-0.03963	0.01616	0.08889	0.28726	0.74138	0.69677
0.62665	0.71676	0.83877	0.73847	0.69713	0.62940	0.71741	0.83880	0.72738	0.71181
0.64094	0.72849	0.83737	0.73658	0.62179	0.54842	0.71588	1.00000	0.72507	-0.28032
-0.58887	-0.48849	-0.34049	0.35982	0.35031	0.17850	0.30654	-0.09294	-0.09921	-0.15448
-0.14128	-0.09656	-0.03567	0.27017	0.23763					

ROW 59

-0.72972	-0.10418	-0.26128	0.89689	0.81182	0.74167	0.81033	0.68023	-0.66883	-0.64782
-0.66990	-0.61481	-0.39151	0.80140	0.75783	0.69527	0.73794	0.69839	0.43970	0.43101
0.47578	0.42668	0.28032	0.42417	0.26882	0.09853	0.30463	0.31740	0.44573	0.49229
0.39995	0.39712	0.30098	0.30492	-0.03521	0.03644	0.04149	0.30119	0.89819	0.81890
0.76618	0.82535	0.81690	0.89856	0.82059	0.77051	0.80636	0.81976	0.90017	0.84641
0.78850	0.82510	0.83920	0.99731	0.77869	0.71026	0.74545	0.72507	1.00000	-0.34977
-0.68870	-0.52321	-0.39130	0.27869	0.49823	0.34101	0.18041	-0.28025	-0.06794	-0.09803
-0.09712	-0.07096	-0.01635	0.26374	0.22514					

ROW 60

0.13263	-0.02620	0.02900	-0.19895	-0.08228	-0.03778	-0.10135	-0.05035	0.52088	0.32584
0.24527	0.22080	0.19421	-0.15801	-0.11736	-0.09240	-0.13115	-0.16773	-0.17077	-0.04185
-0.06009	-0.04844	-0.03242	-0.09168	0.03753	0.00865	0.04881	-0.01702	-0.16573	0.03409
0.08406	0.05730	-0.03426	-0.03481	0.13389	0.01771	0.02322	0.01192	-0.20957	-0.08847
-0.04724	-0.08723	-0.12600	-0.21376	-0.09061	-0.05025	-0.08884	-0.12955	-0.25906	-0.13636
-0.06946	-0.13031	-0.17984	-0.36673	-0.04071	-0.00919	-0.12334	-0.28032	-0.34977	1.00000
0.45742	0.30912	0.26048	-0.31054	-0.54082	-0.26418	-0.04681	-0.20112	-0.05847	-0.00680
-0.02716	-0.03254	-0.13203	-0.06178	0.01578					

ROW 61

0.61171	0.07657	0.06920	-0.58270	-0.52752	-0.48873	-0.55684	-0.50407	0.68843	0.72857
0.79391	0.63577	0.50167	-0.66888	-0.63946	-0.57219	-0.63147	-0.67757	-0.08677	-0.09615
-0.16744	-0.12078	-0.00105	-0.10531	-0.07376	-0.08366	-0.10247	-0.07795	-0.08296	-0.12534
-0.08518	-0.09573	-0.01020	-0.04374	0.12468	-0.08300	-0.13692	-0.04164	-0.58435	-0.52837
-0.49460	-0.54524	-0.55650	-0.58337	-0.52910	-0.49705	-0.54617	-0.55688	-0.58110	-0.55466
-0.50816	-0.56405	-0.56399	-0.67414	-0.52718	-0.44323	-0.60329	-0.58887	-0.68870	0.45742
1.00000	0.67189	0.63765	-0.00068	-0.29299	-0.50911	-0.29404	0.06733	0.05436	0.09282
0.07592	0.06417	-0.00560	-0.09085	0.02697					

ROW 62

0.57585	-0.19753	-0.02860	-0.56501	-0.54620	-0.50790	-0.53113	-0.38600	0.54469	0.70881
0.66358	0.86440	0.59614	-0.59244	-0.60090	-0.49986	-0.54117	-0.56768	-0.12688	-0.12933
-0.20202	-0.14874	0.01827	-0.07713	-0.02707	-0.06157	-0.07625	-0.06086	-0.12994	-0.16005
-0.13096	-0.12337	-0.05855	-0.01263	0.22684	-0.08732	-0.10666	-0.01039	-0.56303	-0.53622
-0.50798	-0.51762	-0.55672	-0.55925	-0.53486	-0.50912	-0.51806	-0.55459	-0.53484	-0.53687
-0.50616	-0.50504	-0.53569	-0.51506	-0.58889	-0.51029	-0.61192	-0.48849	-0.52321	0.30912
0.67189	1.00000	0.75386	-0.00843	-0.26637	-0.22325	-0.55053	0.02301	-0.23339	-0.09714
-0.18444	-0.22761	-0.30861	-0.04530	0.02198					

ROW 63

0.57977	-0.28648	-0.05545	-0.40428	-0.40633	-0.39653	-0.41309	-0.21616	0.59290	0.66910
0.54457	0.75735	0.76949	-0.53399	-0.55055	-0.46904	-0.50715	-0.53595	0.06420	0.03868
-0.04572	0.00682	0.19423	0.09520	0.10949	0.01780	0.02833	0.12638	0.04645	0.02855
0.03086	0.04598	0.13983	0.15048	0.24442	-0.01385	-0.00834	0.19595	-0.39829	-0.40287
-0.39999	-0.40527	-0.39133	-0.39571	-0.40255	-0.40177	-0.40627	-0.38895	-0.36732	-0.40655
-0.40254	-0.39823	-0.36586	-0.37489	-0.45328	-0.38752	-0.47778	-0.34049	-0.39130	0.26048
0.63765	0.75386	1.00000	0.14223	-0.18395	-0.31988	-0.31422	-0.10098	-0.28937	-0.20161
-0.25122	-0.28754	-0.31328	0.10618	0.19123					

ROW 64

0.11911	0.15252	0.22958	0.33911	0.25939	0.20616	0.23136	0.28770	0.04310	0.07850
0.01317	-0.09583	-0.07076	-0.09730	-0.09485	-0.07352	-0.09598	-0.11147	0.74071	0.60472
0.55734	0.58410	0.66728	0.44977	0.24362	0.15152	0.18315	0.40901	0.73355	0.35338
0.20668	0.27529	0.65430	0.39494	0.15394	0.12722	0.12099	0.36689	0.33528	0.25160
0.19019	0.22585	0.34084	0.33432	0.25049	0.18790	0.22616	0.34693	0.36347	0.26408
0.18797	0.24755	0.39117	0.34577	0.24707	0.11151	0.15453	0.35982	0.27869	-0.31054
-0.00068	-0.00843	0.14223	1.00000	0.43126	0.08811	0.07076	-0.15027	0.18380	0.14378
0.16533	0.16943	0.19051	0.38030	0.42004					

ROW 65

-0.25176	0.16733	-0.01012	0.44421	0.36055	0.32750	0.33341	0.25310	-0.39158	-0.25754
-0.29171	-0.33689	-0.15460	0.25667	0.23644	0.21279	0.22124	0.14567	0.41286	0.32665
0.35150	0.30158	0.25093	0.32811	0.26582	0.18715	0.16709	0.26809	0.36830	0.26665
0.24636	0.22301	0.26416	0.33794	0.03535	0.12304	0.02567	0.25213	0.44525	0.36087
0.33038	0.32107	0.37642	0.44387	0.36176	0.33103	0.32180	0.37833	0.45325	0.37781
0.33398	0.33675	0.39574	0.51999	0.37202	0.30876	0.25730	0.35031	0.49823	-0.54082
-0.29299	-0.26637	-0.18395	0.43126	1.00000	0.47864	0.02947	-0.04426	0.21025	0.14672
0.16956	0.19094	0.27718	0.29187	0.28495					

ROW 66

-0.20951	0.02250	0.04156	0.27447	0.26591	0.31261	0.29065	0.26673	-0.30526	-0.21108
-0.31566	-0.22130	-0.24629	0.26174	0.27787	0.30844	0.28113	0.23757	0.13678	0.12881
0.23167	0.15928	0.10481	0.16669	0.13871	0.26081	0.12852	0.11569	0.06799	0.11187
0.14546	0.11463	0.09199	0.18413	0.07066	0.22550	0.20912	0.14789	0.26736	0.25463
0.29746	0.27855	0.25178	0.26724	0.25398	0.29396	0.27888	0.25352	0.27813	0.27731
0.29120	0.30490	0.27886	0.34119	0.25541	0.24245	0.25407	0.17850	0.34101	-0.26418
-0.50911	-0.22325	-0.31988	0.08811	0.47864	1.00000	0.13920	-0.16278	0.03652	0.07487
0.04200	0.02072	0.05058	0.12745	0.16967					

ROW 67

-0.29519	0.23072	-0.01032	0.33511	0.35812	0.33160	0.32478	0.26258	-0.04331	-0.38509
-0.24511	-0.43183	-0.42807	0.24187	0.25957	0.19938	0.19074	0.25475	0.21623	0.25314
0.29665	0.27452	0.16757	0.19426	0.13247	0.11202	0.20158	0.19392	0.22883	0.26830
0.26850	0.30729	0.27426	0.09793	-0.05812	0.13959	0.11862	0.18685	0.33097	0.34886
0.32842	0.31543	0.36379	0.32871	0.34685	0.32654	0.31527	0.36076	0.30454	0.33242
0.31346	0.29977	0.33998	0.18428	0.32931	0.28722	0.39881	0.30654	0.18041	-0.04681
-0.29404	-0.55053	-0.31422	0.07076	0.02947	0.13920	1.00000	-0.14972	0.26378	0.23746
0.25098	0.26701	0.26899	0.18389	0.14441					

ROW 68

0.20798	-0.09446	0.01226	-0.22720	-0.16012	-0.14309	-0.12974	-0.20712	0.02141	0.00463
0.03371	0.15870	0.18401	-0.15646	-0.12243	-0.11537	-0.07611	-0.04547	-0.17397	-0.12137
-0.11859	-0.12452	-0.15776	-0.18066	-0.01542	-0.07595	-0.12374	-0.13137	-0.16229	-0.16409
-0.07515	-0.10013	-0.18679	-0.19044	0.01524	-0.09964	-0.14899	-0.17310	-0.21400	-0.15534
-0.13014	-0.13547	-0.19729	-0.21168	-0.15487	-0.12662	-0.13525	-0.19702	-0.17993	-0.15598
-0.11896	-0.13669	-0.18235	-0.28156	-0.21787	-0.08977	-0.06665	-0.09294	-0.28025	-0.20112
0.06733	0.02301	-0.10098	-0.15027	-0.04426	-0.16278	-0.14972	1.00000	-0.10552	-0.16349
-0.11251	-0.09770	-0.10409	-0.10917	-0.20227					

ROW 69

-0.19334	0.98543	0.21948	0.01409	-0.01756	-0.05489	-0.04427	-0.21983	-0.15502	-0.07371
0.22428	-0.31895	-0.28211	-0.20515	-0.18113	-0.28175	-0.25522	-0.34231	0.28290	0.18156
0.22551	0.25115	0.20222	0.26775	0.16714	0.00818	0.28727	0.31610	0.27193	0.19623
0.27022	0.26800	0.25685	0.25018	-0.23810	-0.07266	-0.10257	0.14902	0.02420	-0.01637
-0.05498	-0.05754	-0.03621	0.02795	-0.01414	-0.05177	-0.05672	-0.03723	0.02612	-0.01294
-0.05034	-0.07257	-0.04673	-0.05243	0.05482	-0.04374	-0.03308	-0.09921	-0.06794	-0.05847
0.05436	-0.23339	-0.28937	0.18380	0.21025	0.03652	0.26378	-0.10552	1.00000	0.94449
0.98837	0.99560	0.97243	0.39932	0.30591					

ROW 70

-0.16072	0.95794	0.19585	-0.04586	-0.07841	-0.10875	-0.08375	-0.23607	-0.13078	0.01932
0.25524	-0.19372	-0.23365	-0.25595	-0.23843	-0.33861	-0.29892	-0.38000	0.25010	0.15142
0.20477	0.24169	0.19835	0.25959	0.14626	-0.01030	0.27642	0.30276	0.23784	0.17634
0.27022	0.26983	0.25127	0.24753	-0.23702	-0.09494	-0.11624	0.14593	-0.03326	-0.07211
-0.10062	-0.09565	-0.09383	-0.02894	-0.06914	-0.09669	-0.09501	-0.09500	-0.03288	-0.06779
-0.09373	-0.11181	-0.10969	-0.08592	-0.01241	-0.09240	-0.07420	-0.15448	-0.09803	-0.00680
0.09282	-0.09714	-0.20161	0.14378	0.14672	0.07487	0.23746	-0.16349	0.94449	1.00000
0.96954	0.95002	0.88713	0.39218	0.30755					

ROW 71

-0.17076	0.99016	0.21967	-0.02130	-0.05496	-0.08660	-0.06868	-0.23747	-0.13007	-0.02312
0.24212	-0.26478	-0.24098	-0.24054	-0.21789	-0.31733	-0.28322	-0.37304	0.26901	0.16305
0.21046	0.24487	0.20221	0.27408	0.17255	-0.00374	0.31411	0.32630	0.25215	0.18900
0.27913	0.27778	0.25320	0.26165	-0.24726	-0.09545	-0.10453	0.17218	-0.00918	-0.05167
-0.08348	-0.08317	-0.07020	-0.00480	-0.04892	-0.07961	-0.08245	-0.07131	-0.00752	-0.04786
-0.07689	-0.10030	-0.08390	-0.08297	0.00833	-0.07005	-0.05746	-0.14128	-0.09712	-0.02716
0.07592	-0.18444	-0.25122	0.16533	0.16956	0.04200	0.25098	-0.11251	0.98837	0.96954
1.00000	0.99021	0.95172	0.40981	0.32163					

ROW 72

-0.19503	0.98625	0.20542	0.01107	-0.02061	-0.05839	-0.04277	-0.22409	-0.14292	-0.05857
0.22209	-0.31316	-0.26152	-0.20890	-0.18518	-0.28880	-0.25706	-0.34551	0.28035	0.17805
0.22171	0.25273	0.19994	0.27408	0.16739	-0.01768	0.29739	0.32275	0.27071	0.20498
0.28127	0.28014	0.26114	0.25631	-0.25446	-0.10163	-0.11761	0.16079	0.02181	-0.01907
-0.05756	-0.05712	-0.03808	0.02575	-0.01666	-0.05380	-0.05638	-0.03928	0.02296	-0.01653
-0.05123	-0.07466	-0.05099	-0.05666	0.04497	-0.04107	-0.02737	-0.09656	-0.07096	-0.03254
0.06417	-0.22761	-0.28754	0.16943	0.19094	0.02072	0.26701	-0.09770	0.99560	0.95002
0.99021	1.00000	0.96469	0.40633	0.31174					

ROW 73

-0.25639	0.94556	0.16320	0.06434	0.03089	-0.00297	0.00304	-0.18004	-0.23175	-0.13186
0.14819	-0.39443	-0.29675	-0.13891	-0.11821	-0.22357	-0.19661	-0.29027	0.27661	0.18024
0.23762	0.25217	0.19352	0.24707	0.14048	0.00308	0.27511	0.30837	0.27419	0.19222
0.25728	0.25812	0.24690	0.21086	-0.26838	-0.07107	-0.12340	0.14092	0.07538	0.03169
-0.00342	-0.01072	0.02077	0.07904	0.03406	0.00004	-0.00983	0.01999	0.07715	0.03715
0.00229	-0.02557	0.01019	-0.00026	0.10168	0.02058	0.02140	-0.03567	-0.01635	-0.13203
-0.00560	-0.30861	-0.31328	0.19051	0.27718	0.05058	0.26899	-0.10409	0.97243	0.88713
0.95172	0.96469	1.00000	0.37776	0.27370					

ROW 74

-0.03447	0.37934	0.15064	0.33961	0.30443	0.24998	0.27736	0.25926	-0.03118	-0.03463
-0.02351	-0.11611	0.02816	-0.14774	-0.14775	-0.16128	-0.17863	-0.22067	0.78654	0.74843
0.72056	0.76362	0.77170	0.88887	0.82813	0.30819	0.81736	0.92941	0.72920	0.80689
0.82771	0.85358	0.79236	0.86320	0.22705	0.15428	0.23285	0.80719	0.34529	0.30105
0.23718	0.25550	0.31906	0.34920	0.30114	0.23199	0.25558	0.32254	0.38312	0.30722
0.23056	0.26331	0.36093	0.28373	0.29465	0.17500	0.23394	0.27017	0.26374	-0.06178
-0.09085	-0.04530	0.10618	0.38030	0.29187	0.12745	0.18389	-0.10917	0.39932	0.39218
0.40981	0.40633	0.37776	1.00000	0.90259					

ROW 75

0.08334	0.28655	0.21238	0.31574	0.26632	0.22975	0.23564	0.23996	0.10852	0.07346
0.02986	-0.02837	0.06381	-0.18706	-0.17288	-0.14688	-0.19521	-0.25569	0.79765	0.71479
0.66083	0.71214	0.77389	0.89985	0.79748	0.33374	0.77880	0.92635	0.71850	0.76644
0.74735	0.77738	0.78205	0.92794	0.30243	0.18843	0.31514	0.88609	0.31336	0.26025
0.20889	0.21659	0.30990	0.31518	0.25953	0.20688	0.21654	0.31310	0.33441	0.26051
0.20075	0.22307	0.34065	0.24734	0.24348	0.14776	0.17281	0.23763	0.22514	0.01578
0.02697	0.02198	0.19123	0.42004	0.28495	0.16967	0.14441	-0.20227	0.30591	0.30755
0.32163	0.31174	0.27370	0.90259	1.00000					

75 as illustrated below:

Row 1 (Variable 1)

variable 1	variable 2	variable 3	...
...	...	...	
variable 73	variable 74	variable 75	

For example, elevation (row 1) is positively correlated with monthly precipitation totals (sequence numbers 9, 10, 11, 12, 13). Extremely good correlations of .71 to .79 for the months May, June and August with good correlations of .56 and .52 result for July and September, respectively. These latter lower values indicate to some degree the type of rainfall experienced in the area. As pointed out in a previous chapter, July is the month of maximum convective activity. Increasing precipitation with increasing elevation denotes the importance of orographic precipitation during the months of May, June and August. In August, with the "differential heating . . . restricted to southern slopes during August," the primary result of convective precipitation will therefore be experienced in upland areas (Geiger, 1965). Lesser preference for upland areas by convective storms is demonstrated in the lower July correlation coefficient. The greater frequency of frontal activity reduces both the orographic and convectional precipitational effects in higher areas such that the resulting coefficient is also lower for the month of September.

Application of the t-test for the significance of correlation coefficients demonstrates the level above which meaningful correlations of variables are found. With 51 degrees of freedom, the level of significance at the probability level of .01 is ±.38. Thus, in referring to the correlation coefficient matrix, those values greater than ±.38 prove statistically significant.

Through the subtraction of a general eigenvalue from each diagonal element in the correlation coefficient, a series of eigenvalues equal to the number of input variables was computed. A practical simplified example of the formulation of the characteristic roots is provided in Appendix A as outlined by Prof. K. D. Hage (1969). Subsequent calculation of the associated column vector of eigenvectors per eigenvalue is also shown in Appendix A.

For the present case, the eigenvalues are presented in Table 8.4 with the associated cumulative explained proportion of the total variance per eigenvalue also shown. Since the purpose of factor analysis is the reduction of a large number of variables to only those factors which are most important statistically, the latter table provides this required limit. Firstly, if only those eigenvalues greater than unity are considered, the first nine characteristic roots are then able to explain 91.6 per cent of the total variance. Secondly, if the rule of thumb, as outlined by King is followed, "at least 5 per cent of the total variance," then only the first three eigenvalues need be considered in the subsequent analysis (King, 1969, p. 174). Three quarters of the total variance is attributable to these eigenvalues.

Therefore, in the calculation of the associated factor matrix, only the first three vectors of coefficients are needed as shown in Table 8.5. Any intercorrelations inherent in the original input variables are, at this point, presented as independent factors usually referred to as orthogonal factors. Orthogonality, or rotation of the axis, is able to provide a set of factors "which has the property that any given factor will be fairly highly correlated with some indices

Table 8.4

EIGENVALUES AND CUMULATIVE PROPORTION OF TOTAL VARIANCE

EIGENVALUES	CUMULATIVE PROPORTION OF TOTAL VARIANCE	EIGENVALUES	CUMULATIVE PROPORTION OF TOTAL VARIANCE
35.26	0.47	0.02	0.99
14.13	0.65	0.01	0.99
6.89	0.75	0.01	0.99
3.63	0.79	0.01	0.99
2.70	0.83	0.01	0.99
2.00	0.86	0.00	0.99
1.66	0.88	0.00	0.99
1.37	0.90	0.00	0.99
1.04	0.91	0.00	0.99
0.93	0.92	0.00	0.99
0.75	0.93	0.00	0.99
0.64	0.94	0.00	0.99
0.54	0.95	0.00	0.99
0.48	0.96	0.00	0.99
0.42	0.96	0.00	0.99
0.32	0.97	0.00	0.99
0.30	0.97	0.00	0.99
0.25	0.97	0.00	0.99
0.20	0.98	0.00	0.99
0.18	0.98	0.00	0.99
0.14	0.98	0.00	0.99
0.13	0.98	0.00	0.99
0.11	0.98	0.00	0.99
0.10	0.99	0.00	0.99
0.10	0.99	0.00	0.99
0.07	0.99	0.00	0.99
0.07	0.99	0.00	0.99
0.06	0.99	0.00	0.99
0.05	0.99	0.00	0.99
0.04	0.99	0.00	0.99
0.03	0.99	0.00	0.99
0.03	0.99	-0.00	0.99
0.03	0.99	-0.00	0.99
0.02	0.99	-0.00	0.99
0.02	0.99	-0.00	0.99

Table 8.4 Contd.

EIGENVALUES	CUMULATIVE PROPORTION OF TOTAL VARIANCE
-0.00	0.99
-0.00	0.99
-0.00	0.99
-0.00	0.99
-0.00	0.99

Table 8.5

SELECTED FACTOR MATRIX OF INPUT VARIABLES

VARIABLE NUMBER	I	II	III	VARIABLE NUMBER	I	II	III
1	-.70	.42	.40	38	.53	.68	.20
2	.006	.45	-.86	39	.98	-.09	-.01
3	-.20	.26	-.080	40	.97	-.11	.06
4	.98	-.087	.004	41	.94	-.15	.09
5	.97	-.100	.071	42	.96	-.17	.05
6	.92	-.115	.127	43	.96	-.11	.04
7	.97	-.155	.040	44	.98	-.085	-.018
8	.834	-.116	.244	45	.97	-.113	.052
9	-.52	.34	.41	46	.94	-.155	.09
10	-.65	.439	.316	47	.96	-.17	.048
11	-.64	.44	.006	48	.96	-.11	.043
12	-.65	.31	.53	49	.97	-.049	-.008
13	-.40	.286	.47	50	.98	-.12	.03
14	.75	-.62	-.027	51	.95	-.17	.07
15	.76	-.60	-.016	52	.96	-.17	.06
16	.71	-.56	.15	53	.96	-.08	.06
17	.73	-.63	.04	54	.86	-.16	-.02
18	.67	-.68	.08	55	.92	-.096	-.02
19	.62	.71	.06	56	.88	-.189	-.049
20	.68	.63	.17	57	.90	-.21	-.04
21	.73	.57	.08	58	.74	-.160	.025
22	.69	.62	.04	59	.86	-.199	-.02
23	.54	.73	.16	60	-.17	.099	.214
24	.56	.75	.08	61	-.587	.39	.19
25	.48	.68	.02	62	-.568	.31	.44
26	.23	.31	.28	63	-.41	.42	.56
27	.52	.62	.03	64	.33	.45	.03
28	.53	.78	.04	65	.43	.11	-.17
29	.63	.64	.03	66	.32	-.05	-.08
30	.71	.59	.099	67	.375	.039	-.289
31	.63	.61	.03	68	-.0188	-.087	.057
32	.63	.65	.03	69	.053	.453	-.85
33	.55	.73	.07	70	-.001	.474	-.80
34	.43	.76	.12	71	.02	.478	-.84
35	.08	.33	.56	72	.05	.46	-.85
36	.13	.18	.29	73	.10	.396	-.86
37	.18	.22	.32	74	.44	.80	-.06
				75	.40	.82	.06

(coefficients of the factor matrix) but uncorrelated with the rest" (Blalock, 1960, p. 385).

Factor one, therefore, is best described as an indicator of general climate. Accounting for 57 per cent of the total variance, the dominant variable coefficients are: negative elevation, mean daily temperature (all five months), May to August mean daily maximum temperature, July mean daily minimum temperature, mean number of June days above 42°F., degree-days above all three base temperatures (32, 28, 42) for all five months, mean monthly potential evapotranspiration (all five months) and mean May actual evapotranspiration.

The second factor, accounting for 19 per cent of the variance, is generally an indicator of selected May and September thermal values and frost-free periods. The selected temperature variables consist of May and September minimum temperatures, May and September mean number of days above 32°F., September mean number of days above 42°F., and May mean number of days above 28°F.

The third "important" factor, accounting for only 9 per cent of the total variance, is denoted by photoperiod and latitude variables. High negative dependence is placed upon day length for all five months and latitude such that higher factor scores are found for the more northerly stations in the study area.

This therefore completes the number and characteristics of the factors to be considered for later alogarthmic grouping procedures.

Factor Scores

The coefficients of each of these above three factors generate general indices per station in the form of factor scores. Factor scores

are the representation of the factor loadings (coefficients of the factor matrix) in conjunction with the normalized raw input data. The input raw data is firstly reduced to a mean of zero and unit variance and substituted into the formula:

$$Z = a_{k1} x_1 + a_{k2} x_2 + \ldots + a_{k75} x_{75} \qquad (1)$$
$$(k = 1, 2, \ldots 3)$$

where Z, is the factor score 1, a_{11} is the first vector value of the factor loading, and x_1 is the normalized input variable 1. Calculation of three factor scores per 53 stations in the study area yielded the required numerical values for grouping.

Simple graphical plotting in two-dimensions of Z_1 vs Z_2 indicates an extremely dispersed set of stations as illustrated in Figure 8.1. This failure of the like-stations to cluster distinctly, thereby necessitated a different analysis approach. Since the first three factors were found to be statistically significant, utilization of three dimensional plotting of the station indices maximized the inter-group distances and minimized the intra-group dispersion.

Algorithmic Grouping Method

The data input consists of a set of three factor indices per station as shown in Table 8.6. Based upon Mahalonhis, (King, 1969) the basic formula derives a distance statistic D^2 between pairs of stations according to the following:

$$D^2_{ab} = \sum_{i=1}^{p} \sum_{j=1}^{p} S^{ij} d_i d_j$$

where

$d_i = \overline{X}_{ia} - \overline{X}_{ib}$ the difference in the two group's means on variate i

SCATTERDIAGRAM OF FACTOR 1 vs FACTOR 2 FOR THE STUDY AREA STATIONS

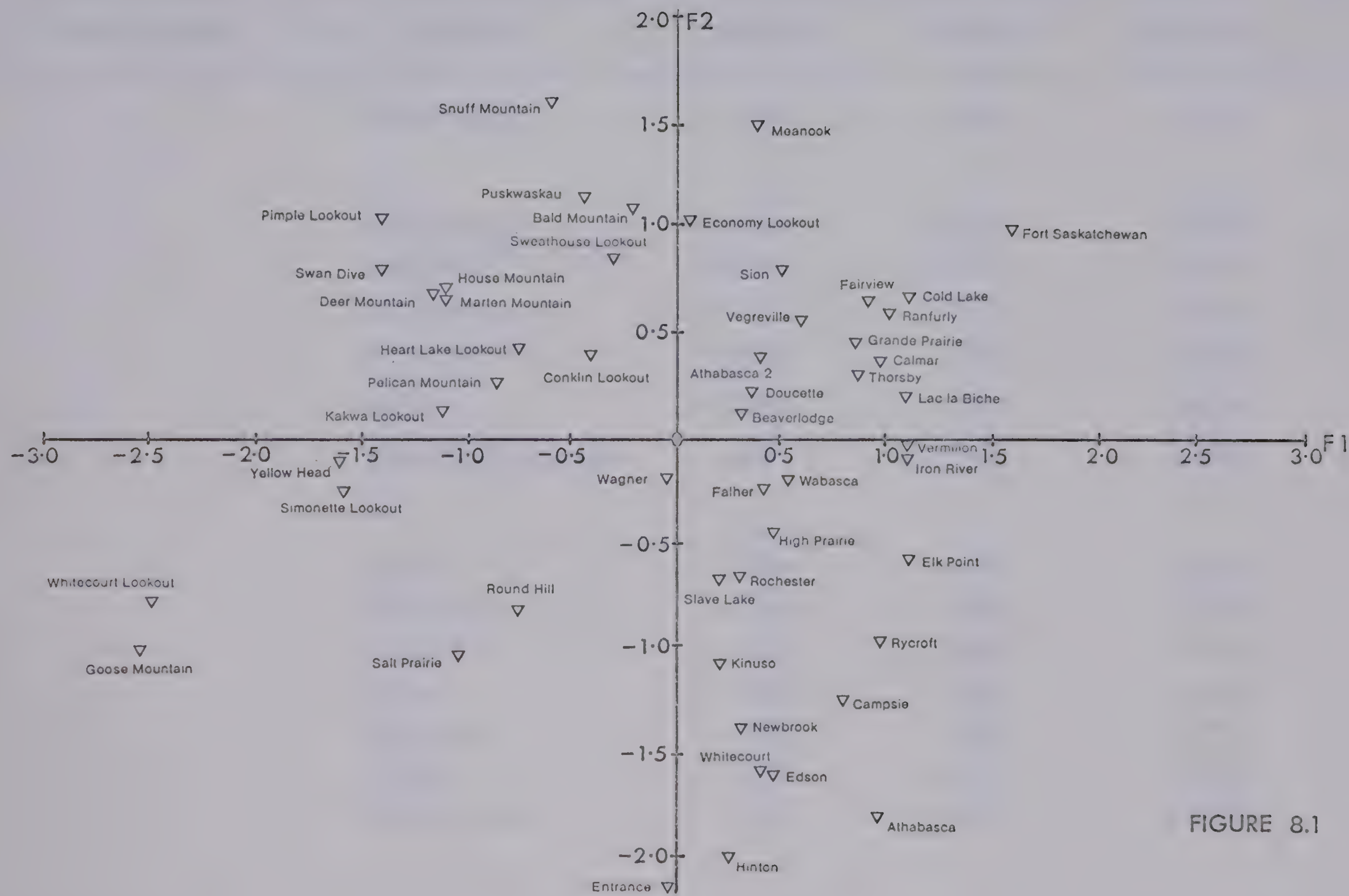


FIGURE 8.1

Table 8.6

ALOGARITHMICALLY GROUPED FACTOR SCORES PER STATION

GROUP NUMBER	STATION	FACTOR 1	FACTOR 2	FACTOR 3
1	Athabasca 2	.4354	.3788	-.0318
2	Yellowhead	-1.6216	-0.1124	-1.7843
	Goose Mtn	-2.6930	-1.0332	.0849
	Whitecourt Lo.	-2.6179	-.7900	-.9945
	Simonette Lo.	-1.6058	-.2357	-.5285
	MEAN	-2.1346	-.5428	-.8056
	STANDARD DEVIATION	±.6023	±.4401	±.7881
3	Rycroft	.9765	-.9715	1.6280
	Round Hill	-.7583	-.8259	.9467
	Conklin	-.4328	.3637	1.1989
	Wabasca	.5268	-.2251	1.6133
	Slave Lake	.2093	-.6850	.9842
	Kinuso	.2179	-1.0293	.9665
	High Prairie	.4609	-.4656	1.0277

GROUP NUMBER	STATION	FACTOR 1	FACTOR 2	FACTOR 3
3	Falher	.4244	-.2480	1.6017
	Salt Prairie	-1.0180	-1.0247	1.5529
	Wagner	.0519	-.1926	.9900
	MEAN	.0659	-.5304	1.2510
	STANDARD DEVIATION	±.6212	±.4582	±.3078
4	Snuff Mtn	-.6832	1.6031	-.4517
	Sweathouse	-.3498	.8817	-.0171
	Puskwaskaw	-.4402	1.1712	.3586
	Economy	.0614	1.0095	-.0462
	Bald Mtn	-.1988	1.1218	-.1279
	MEAN	-.3221	1.1575	-.0569
	STANDARD DEVIATION	±.2772	±.2729	±.2895
5	Calmar	.9947	.3786	-1.8688
	Thorsby	.7737	.3280	-1.7708

GROUP NUMBER	STATION	FACTOR 1	FACTOR 2	FACTOR 3
5	MEAN	.8842	.3533	-1.8198
	STANDARD DEVIATION	±.1563	±.0358	±.0693
6	Vermilion A	1.1387	-.0839	-1.4115
7	Doucette	.3492	.2218	1.5939
	Grande Prairie	.8542	.4686	.6724
	Beaverlodge	.3180	.1170	.6469
	Fairview	.9209	.6593	1.7381
	MEAN	.6106	.3667	1.1628
	STANDARD DEVIATION	±.3212	±.2445	±.5840
8	Meanook	.3650	1.5404	-.4295

GROUP NUMBER	STATION	FACTOR 1	FACTOR 2	FACTOR 3
9	Iron River	1.0735	-.0790	-0.0732
	Lac la Biche	1.0973	.2130	.2117
	Cold Lake	1.2180	.6621	-.1478
	MEAN	1.1296	.2654	-.0031
	STANDARD DEVIATION	±.0775	±.3733	±.1897
10	Swan Dive	-1.3858	.8136	-.3632
	House Mtn	-1.1124	.7334	.2341
	Pimple Mtn	-1.4976	1.0676	-.6449
	Marten Mtn	-1.2689	.6999	.7995
	Pelican Mtn	-.7902	.2896	1.1783
	Heart Lake	-.7516	.4451	.3223
	Kakwa Mtn	-1.2103	.1368	-.3926
	Deer Mtn	-1.2089	.6913	-.0051
	MEAN	-1.153	.6097	.1411
	STANDARD DEVIATION	±.2638	±.3011	±.6244

GROUP NUMBER	STATION	FACTOR 1	FACTOR 2	FACTOR 3
11	Newbrook	.3072	-1.3898	-.1074
	Campsie	.7868	-1.2584	-.3543
	Edson	.4717	-1.6848	-1.0323
	Hinton	.2439	-2.0093	-1.2086
	Entrance	-.0762	-2.3779	-1.2248
	Whitecourt	.3697	-1.6861	-.2694
	Athabasca	.9165	-1.8288	.4973
	MEAN	.4314	-1.7479	-.5285
	STANDARD DEVIATION	±.3355	±.3758	±.6491
12	Rochester	.3072	-.6598	-.3743
	Elk Point	1.1056	-.5968	-.6374
	MEAN	.7064	-.6283	-.5059
	STANDARD DEVIATION	±.5646	±.0445	±.1861
13	Ranfurly	1.0086	.6081	-1.5295

GROUP NUMBER	STATION	FACTOR 1	FACTOR 2	FACTOR 3
13	Vegreville	.5862	.6633	-1.5952
	Ft. Saskatchewan	1.6146	1.0165	-1.2248
	Sion	.5094	.8072	-.9986
	MEAN	.9297	.7735	-1.3370
	STANDARD DEVIATION	±.5066	±.1825	±.2774

$$d_j = \overline{X}_{ja} - \overline{X}_{jb} \quad (\text{for } (i, j = 1, 2, \ldots, p)$$

and $S^{ij} = (Sij)^{-1}$ the element of the inverse of the common dispersion matrix.

Modification of a computer program by Semple, Cassetti and King for the IBM/360 enabled the 52 stations to be classified into similar groups. Each group is able to explain at least 1 per cent of the total variance with all groups explaining 75 per cent of the total variance. In this particular case, using the above criteria, the 52 stations were delineated into 13 groups or like-regions. The mean and standard deviations of each group are presented in Table 8.6.

In order to test the reliability of this technique, three stations--Beaverlodge, Thorsby and Deer Mountain Lookout, were substracted from the original input for factor analysis. Subsequent, substitution of the normalized variables into the general study area formula (1) yielded three sets of three factors. By applying the resulting factor scores to the class divisions as outlined in Table 8.6, Beaverlodge grouped into region 7, Thorsby into group 5 and Deer Mountain into group 10. Each station grouped into the expected class associations.

Additional stations not within the study area but in close proximity, or stations within the study area but not included in the analysis, can easily be added to the existing climatic zonations. Calculation of the factor scores according to formula (1) and placing of the respective scores within the limits defined by Table 8.6, provides the resulting climatic type. If, however, the factor scores do not fit the classes described, reanalysis of the study area data bank

with the associated additional stations is not a complex process by employing the original procedure, as outlined in the above Chapter.

Chapter 9

Results of the Climatic Statistical Analysis

Arising out of the 53 input stations were thirteen climates, but is this the required scale? To better answer this question different levels of significance were set such that groupings of the stations were accomplished at various cluster levels.

Results of Preliminary Analysis

The grouping procedure outlined in the latter part of Chapter 8 indicates the dependence of the clustering of stations upon the distance between the three-dimensional factor score co-ordinates. Discriminant iteration at various levels of significance per group identifies the similar indices. Iteration is a method of combining the station values through minimization of the inter-group variation. Two types of levels of significance can be stipulated - explained variance per group and/or the cumulative explained variance for all groups. Reducing the explained variance per group allows the classifier to alter the number of the clusters.

If for example, the least explained variance per group is set at 3% and the cumulative explained variance at 95% with 30 iterations, the number of climatic areas is four. Alteration of the explained variance per group from 3% to 2% yields 9 climatic areas. At the scale deemed to best fit the prescribed objectives, a least explained group variance of 1% was used such that the resulting climatic areas are thirteen in number. The factor scores and groupings of the stations into these thirteen clusters is illustrated

in the previous Chapter, as Table 8.6.

The unsmoothed generalized map of the climatic areas at the 1% level is shown as Figure 9.1. It is unsmoothed since there is no fitting of the climatic boundaries through application of the mobile traverses, as yet. Cross-checking of this map with the topographic map in Chapter 3, Figure 3.3, illustrates some interesting correlations. Stations such as Kakwa, House, Deer, Pimple, Marten and Pelican Mountains, Swan Dive and Heart Lake all appear as one climatic type. Each of these stations is found at relatively higher elevations in the forested regions of the province. Likewise at similar elevations and again forested but indicated by a different climate are the stations Bald, Economy, Snuff, Sweathouse and Puskwaskau. More will be said about particular groups later in the Chapter.

Smoothing of the Areas by Thermo Dew-Point Results

In view of the thermal spatial variations found in Chapter 7 by mobile traversing, the following rules will be followed in smoothing and redefining the climatic boundaries:

1) In the Swan Hills area and at similar Forestry Tower Observation points, the boundaries will be located at the higher elevations. The intervening valleys and rivers will be of different climates, defined if possible by the neighbouring climatic type.

2) In areas surrounding Lesser Slave Lake, the area to the southeast of the lake will be treated as being of the same climatic type of Slave Lake. Areas to the north, south and west will be representative of the near-by station - not adversely affected by the lake.

UNSMOOTHED STATISTICAL CLIMATIC ZONES

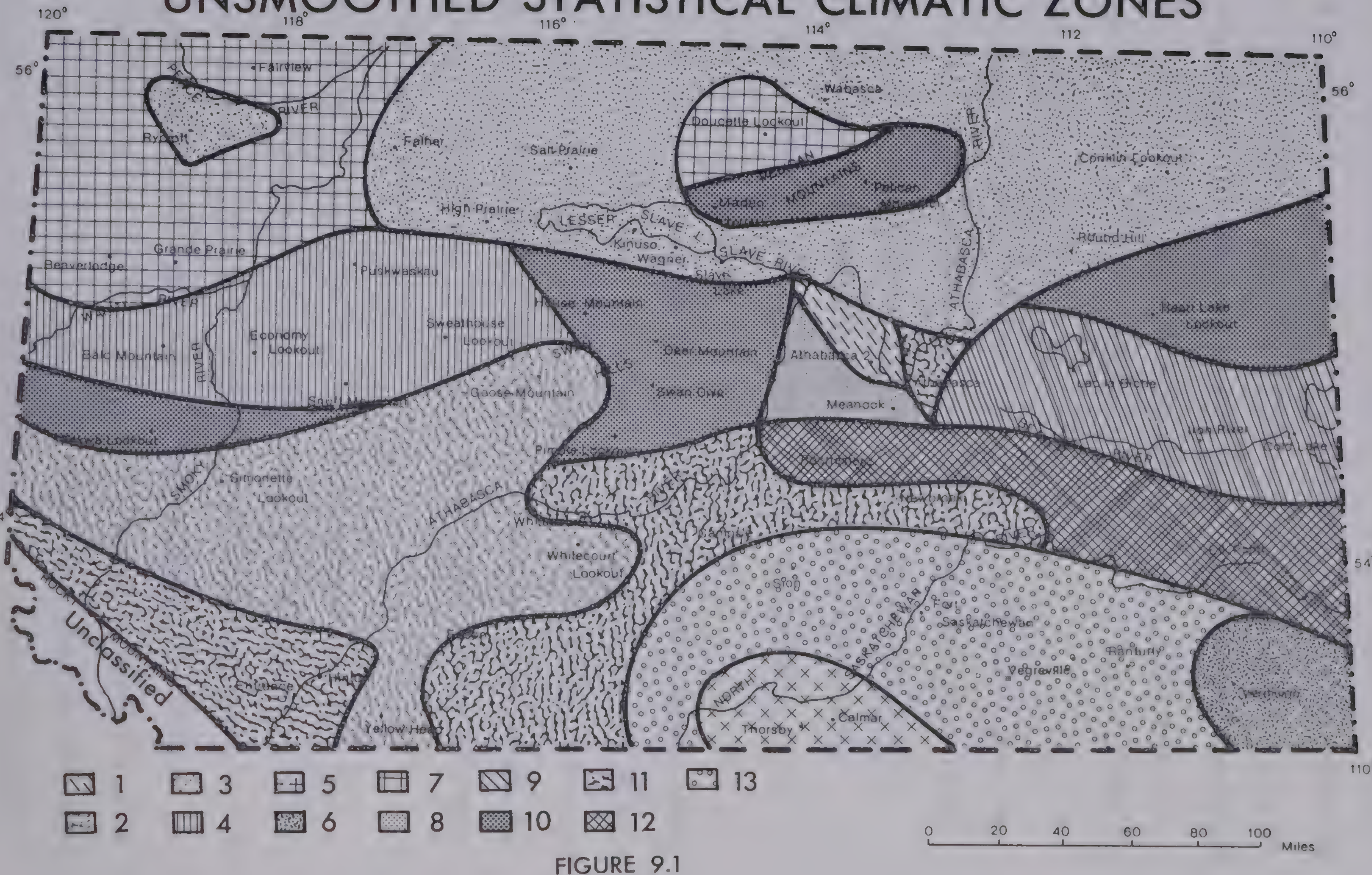


FIGURE 9.1

3) In areas where small lakes are prevalent, the modification of the boundaries will ensue in that again the areas to the southeast of the lakes indicate a modified climatic type, as is the case in the Frog Lake area. Climatic stations in the southeast of the study area and the northwest will be treated as representative of larger regions as indicated by the uniformity in traverses about the Elk Point station.

4) Areas under similar forest stands can be treated as of a relatively uniform climate, the thermal variations being a result of topographical differences. In the case of Spring Creek Basin, as with the Elk Point example, relatively uniform traces were experienced with the temperature fluctuations occurring in direct response to the associated topographic differences.

5) Areas or stations found in the larger river valleys will be treated as unique climatic types. As noted in the case of Hinton, higher maximums and lower minimums in comparison with the surrounding region are characteristic. Consequently, where possible, breaks in the climatic regions and extension of the climatic types will occur along the river valleys.

Utilizing the above "rules", the climatic type found in association with Hinton is extended to join the Whitecourt climatic type which in turn joins the Athabasca climatic region. Each of these stations - Whitecourt, Athabasca, Hinton and Entrance - is found in association with the Athabasca River Valley, each grouping into the same statistical climatic region. The climatic regimes at Athabasca 2 and Meanook will also be diminished in size due to the localized climates in association with each station. Likewise, the station

Doucette was reduced in extent since the elevation tends to localize the effects of the station's climatic range.

In the case of Swan Hills, the boundaries are altered to better fit the topographical variations. Similarly, the Whitecourt Lookout and Yellowhead climatic types will be changed to localized pockets of similar climates. These, therefore, are the major changes due to the above guidelines. One remaining alteration concerns the insufficient data available in the Rocky Mountain region such that this area will be marked, for the present, as unclassified.

Final Climatic Map for the Study Area

Figure 9.2 indicates the groupings of the stations into homogeneous climatic areas. The associated characteristics of each climatic type are illustrated in Table 9.1. In view of the magnitude of the input variables - seventy-five per station - no attempt can be made to point out the predominant variables in each group. It is instead the intercorrelations of these variables which are able to account for similar groupings. Therefore, because of this magnitude, simple descriptions, in the form of the associated data table will be presented.

Interpretation of the final climatic map in view of simply topographical or elevational variations is not sufficient. For example, Athabasca at 1700 feet is climatically similar to Hinton at 3325 feet. It is the resulting characteristic of climatic variation among the seventy-five input variables which accounts for this similarity. Nor are the climatic regions explained by simply mean temperature differences. June mean daily temperature at Wagner of 54.4°F and

SMOOTHED STATISTICAL CLIMATIC ZONES

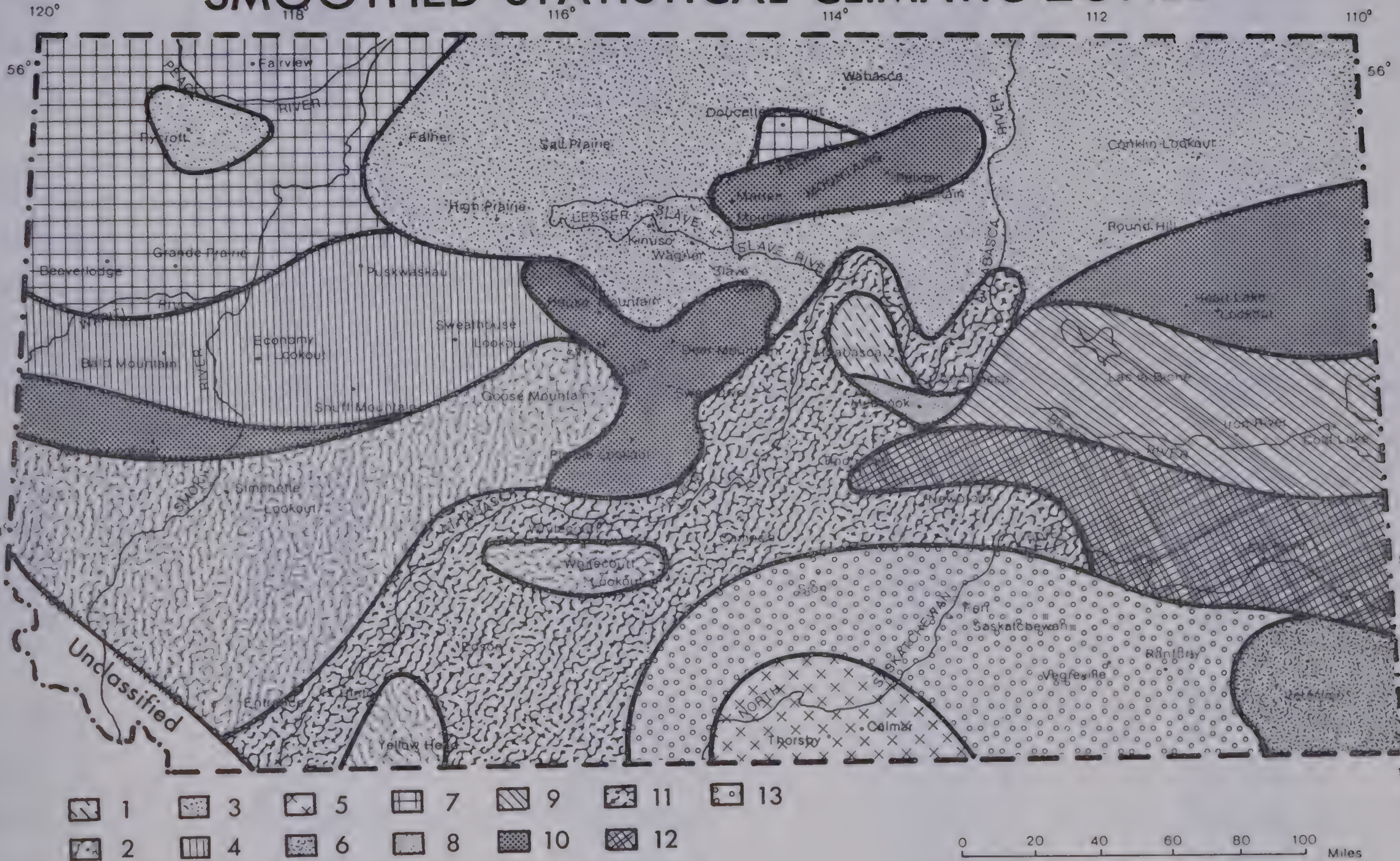


FIGURE 9.2

Table 9.1

Climatic Normals, 1954-1968

(errata: longitudes and latitudes are reversed throughout this table)

CLIMATIC REGION 1

ATHABASCA 2

ELEVATION 1900 FEET LONGITUDE 54 49 0 LATITUDE 113 32 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.6	55.1	58.3	58.3	48.9
MAX. TEMPERATURE (F)	60.5	66.6	69.8	69.8	59.6
DAYS ABOVE 32F (DAYS)	23.	29.	30.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	30.	31.	27.
DEG DAYS ABOVE 32F (F)	525.	706.	849.	817.	508.
POT. EVAPOTRANS. (IN)	2.9	3.9	4.8	4.0	2.3
WATER DEFICIENCY (IN)	0.0	0.2	1.3	1.0	0.5
FROST-FREE PERIOD (DAYS)	110.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.8	2.9	2.9	2.8	1.6
MIN. TEMPERATURE (F)	37.1	44.1	47.3	47.3	38.7
DAYS ABOVE 42F (DAYS)	8.	19.	27.	26.	9.
DEG DAYS ABOVE 28F (F)	645.	323.	968.	941.	627.
DEG DAYS ABOVE 42F (F)	244.	411.	555.	507.	233.
ACT. EVAPOTRANS. (IN)	2.9	3.7	3.5	3.0	1.8
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	133.				

CLIMATIC REGION 2

GOOSE MOUNTAIN LO.

ELEVATION 4500 FEET LONGITUDE 54 45 0 LATITUDE 116 4 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	42.5	48.6	53.5	51.3	43.1
MAX. TEMPERATURE (F)	51.1	57.5	62.9	59.8	51.0
DAYS ABOVE 32F (DAYS)	19.	27.	31.	30.	21.
DAYS ABOVE 28F (DAYS)	26.	30.	31.	31.	26.
DEG DAYS ABOVE 32F (F)	336.	497.	666.	598.	341.
POT. EVAPOTRANS. (IN)	2.5	3.5	4.3	3.6	2.0
WATER DEFICIENCY (IN)	0.0	0.0	0.2	0.2	0.0
FROST-FREE PERIOD (DAYS)	82.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.2	5.3	4.5	4.5	2.4
MIN. TEMPERATURE (F)	34.5	40.2	44.6	43.3	35.8
DAYS ABOVE 42F (DAYS)	3.	10.	20.	16.	6.
DEG DAYS ABOVE 28F (F)	454.	617.	790.	722.	457.
DEG DAYS ABOVE 42F (F)	96.	209.	357.	293.	105.
ACT. EVAPOTRANS. (IN)	2.5	3.5	4.1	3.4	2.0
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	114.				

CLIMATIC REGION 2

SIMONETTE LOOKOUT

ELEVATION 4525 FEET LONGITUDE 54 14 0 LATITUDE 118 25 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	44.5	51.0	55.8	53.9	45.7
MAX. TEMPERATURE (F)	54.0	60.7	65.9	63.8	54.8
DAYS ABOVE 32F (DAYS)	20.	29.	31.	30.	22.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	392.	570.	738.	680.	415.
POT. EVAPOTRANS. (IN)	2.6	3.6	4.4	3.8	2.2
WATER DEFICIENCY (IN)	0.0	0.2	0.5	0.2	0.2
FROST-FREE PERIOD (DAYS)	99.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.7	3.9	3.7	4.4	2.8
MIN. TEMPERATURE (F)	35.5	41.8	46.2	44.6	37.1
DAYS ABOVE 42F (DAYS)	5.	13.	25.	21.	6.
DEG DAYS ABOVE 28F (F)	513.	690.	862.	804.	532.
DEG DAYS ABOVE 42F (F)	135.	275.	428.	372.	157.
ACT. EVAPOTRANS. (IN)	2.6	3.4	3.9	3.6	1.9
DAY - LENGTH (HRS)	15.8	17.0	16.4	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	130.				

CLIMATIC REGION 2

WHITECOURT LOOKOUT

ELEVATION 3800 FEET LONGITUDE 54 1 54 LATITUDE 115 43 10

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	42.9	49.5	52.7	51.9	45.2
MAX. TEMPERATURE (F)	52.6	58.1	60.1	59.3	54.0
DAYS ABOVE 32F (DAYS)	17.	27.	30.	30.	20.
DAYS ABOVE 28F (DAYS)	23.	29.	31.	31.	24.
DEG DAYS ABOVE 32F (F)	344.	526.	640.	616.	399.
POT. EVAPOTRANS. (IN)	2.5	3.6	4.1	3.7	2.3
WATER DEFICIENCY (IN)	0.0	0.0	0.3	0.7	0.5
FROST-FREE PERIOD (DAYS)	92.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.3	3.2	3.5	3.5	1.4
MIN. TEMPERATURE (F)	33.7	41.4	45.7	44.9	36.8
DAYS ABOVE 42F (DAYS)	4.	12.	21.	20.	9.
DEG DAYS ABOVE 28F (F)	465.	646.	764.	740.	516.
DEG DAYS ABOVE 42F (F)	98.	233.	331.	310.	152.
ACT. EVAPOTRANS. (IN)	2.5	3.6	3.8	3.0	1.8
DAY - LENGTH (HRS)	15.8	16.9	16.3	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	115.				

CLIMATIC REGION 2

YELLOWHEAD LOOKOUT

ELEVATION 4800 FEET LONGITUDE 53 14 14 LATITUDE 117 8 30

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	44.1	50.9	55.4	53.7	45.9
MAX. TEMPERATURE (F)	53.4	60.9	66.5	63.7	55.1
DAYS ABOVE 32F (DAYS)	20.	29.	31.	31.	23.
DAYS ABOVE 28F (DAYS)	26.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	379.	568.	728.	673.	421.
POT. EVAPOTRANS. (IN)	2.4	3.6	4.4	3.7	2.2
WATER DEFICIENCY (IN)	0.0	0.0	0.0	0.9	0.2
FROST-FREE PERIOD (DAYS)	92.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	3.0	4.0	3.7	3.7	2.7
MIN. TEMPERATURE (F)	35.3	41.5	44.8	44.2	37.2
DAYS ABOVE 42F (DAYS)	5.	13.	23.	19.	7.
DEG DAYS ABOVE 28F (F)	500.	688.	850.	797.	538.
DEG DAYS ABOVE 42F (F)	128.	272.	423.	365.	165.
ACT. EVAPOTRANS. (IN)	2.4	3.6	4.4	3.4	2.0
DAY - LENGTH (HRS)	15.7	16.5	16.2	14.5	12.5
KILLING FROST-FREE PERIOD (DAYS)	124.				

CLIMATIC REGION 3

CONKLIN LOOKOUT

ELEVATION 2200 FEET — LONGITUDE 55 37 7 — LATITUDE 111 11 17

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	46.9	53.1	56.8	56.6	47.4
MAX. TEMPERATURE (F)	57.5	63.3	65.9	66.2	56.4
DAYS ABOVE 32F (DAYS)	23.	28.	29.	31.	24.
DAYS ABOVE 28F (DAYS)	27.	29.	29.	31.	28.
DEG DAYS ABOVE 32F (F)	477.	642.	787.	763.	466.
POT. EVAPOTRANS. (IN)	2.8	3.8	4.6	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.2	0.4	0.8	0.4
FROST-FREE PERIOD (DAYS)	104.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.5	3.6	4.0	3.4	2.4
MIN. TEMPERATURE (F)	37.0	43.4	48.2	47.6	39.0
DAYS ABOVE 42F (DAYS)	9.	20.	28.	26.	10.
DEG DAYS ABOVE 28F (F)	595.	760.	906.	887.	583.
DEG DAYS ABOVE 42F (F)	210.	353.	495.	455.	202.
ACT. EVAPOTRANS. (IN)	2.8	3.6	4.2	3.1	1.9
DAY - LENGTH (HRS)	16.1	17.3	16.7	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	131.				

CLIMATIC REGION 3

FALHER

ELEVATION 1910 FEET — LONGITUDE 55 45 0 — LATITUDE 117 12 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.6	55.5	59.3	57.1	48.7
MAX. TEMPERATURE (F)	60.5	67.6	71.8	68.8	59.8
DAYS ABOVE 32F (DAYS)	23.	30.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	518.	705.	845.	779.	502.
POT. EVAPOTRANS. (IN)	2.8	4.0	4.5	3.9	2.4
WATER DEFICIENCY (IN)	0.0	0.4	1.4	1.3	0.9
FROST-FREE PERIOD (DAYS)	111.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.8	1.9	2.9	2.8	1.2
MIN. TEMPERATURE (F)	37.2	43.9	47.2	45.9	38.1
DAYS ABOVE 42F (DAYS)	7.	18.	25.	23.	8.
DEG DAYS ABOVE 28F (F)	640.	325.	969.	902.	621.
DEG DAYS ABOVE 42F (F)	231.	405.	535.	470.	225.
ACT. EVAPOTRANS. (IN)	2.8	3.6	3.1	2.6	1.5
DAY - LENGTH (HRS)	16.1	17.3	16.7	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	133.				

CLIMATIC REGION 3

HIGH PRAIRIE RS.

ELEVATION 1958 FEET — LONGITUDE 55 25 30 — LATITUDE 116 29 35

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.7	54.4	59.3	57.5	49.2
MAX. TEMPERATURE (F)	61.3	68.0	71.8	69.6	61.0
DAYS ABOVE 32F (DAYS)	21.	28.	30.	31.	23.
DAYS ABOVE 28F (DAYS)	26.	28.	30.	31.	26.
DEG DAYS ABOVE 32F (F)	521.	674.	853.	791.	517.
POT. EVAPOTRANS. (IN)	3.0	3.8	4.5	4.0	2.4
WATER DEFICIENCY (IN)	0.0	0.5	1.4	1.4	1.0
FROST-FREE PERIOD (DAYS)	96.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.1	2.8	2.5	2.3	1.2
MIN. TEMPERATURE (F)	36.5	41.3	47.2	45.9	37.9
DAYS ABOVE 42F (DAYS)	7.	17.	25.	23.	8.
DEG DAYS ABOVE 28F (F)	643.	793.	975.	915.	636.
DEG DAYS ABOVE 42F (F)	238.	389.	549.	484.	242.
ACT. EVAPOTRANS. (IN)	3.0	3.3	3.1	2.6	1.4
DAY - LENGTH (HRS)	16.0	17.2	16.6	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	129.				

CLIMATIC REGION 3

KINUSO

ELEVATION 1928 FEET — LONGITUDE 55 20 0 — LATITUDE 115 26 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.1	53.8	58.0	56.6	45.5
MAX. TEMPERATURE (F)	61.3	67.7	71.2	69.1	61.0
DAYS ABOVE 32F (DAYS)	20.	27.	30.	31.	22.
DAYS ABOVE 28F (DAYS)	25.	28.	30.	31.	26.
DEG DAYS ABOVE 32F (F)	505.	655.	814.	763.	500.
POT. EVAPOTRANS. (IN)	2.9	3.8	4.5	4.1	2.4
WATER DEFICIENCY (IN)	0.0	0.8	1.3	1.9	1.1
FROST-FREE PERIOD (DAYS)	93.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	0.6	1.9	2.7	2.2	1.3
MIN. TEMPERATURE (F)	35.5	40.4	45.4	44.5	34.5
DAYS ABOVE 42F (DAYS)	6.	15.	24.	22.	6.
DEG DAYS ABOVE 28F (F)	626.	774.	936.	886.	619.
DEG DAYS ABOVE 42F (F)	222.	367.	510.	455.	225.
ACT. EVAPOTRANS. (IN)	2.9	3.0	3.2	2.2	1.3
DAY - LENGTH (HRS)	16.0	17.2	16.6	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	122.				

CLIMATIC REGION 3

ROUND HILL LOOKOUT

ELEVATION 2460 FEET — LONGITUDE 55 18 12 — LATITUDE 111 58 30

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	46.0	51.7	54.4	55.3	46.4
MAX. TEMPERATURE (F)	57.7	63.0	64.4	66.9	57.3
DAYS ABOVE 32F (DAYS)	20.	28.	30.	30.	22.
DAYS ABOVE 28F (DAYS)	25.	29.	30.	31.	25.
DEG DAYS ABOVE 32F (F)	460.	619.	757.	725.	435.
POT. EVAPOTRANS. (IN)	2.7	3.6	4.4	3.8	2.2
WATER DEFICIENCY (IN)	0.0	1.3	0.8	0.8	0.4
FROST-FREE PERIOD (DAYS)	96.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.5	2.9	3.8	3.4	1.8
MIN. TEMPERATURE (F)	34.7	40.8	44.8	44.2	36.0
DAYS ABOVE 42F (DAYS)	6.	14.	24.	21.	6.
DEG DAYS ABOVE 28F (F)	577.	735.	873.	849.	553.
DEG DAYS ABOVE 42F (F)	193.	331.	469.	417.	176.
ACT. EVAPOTRANS. (IN)	2.7	3.3	3.6	3.0	1.8
DAY - LENGTH (HRS)	16.0	17.2	16.6	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	118.				

CLIMATIC REGION 3

RYCROFT

ELEVATION 1983 FEET LONGITUDE 55 46 0 LATITUDE 118 38 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.1	56.1	60.4	58.5	49.3
MAX. TEMPERATURE (F)	62.2	69.1	73.5	71.5	61.7
DAYS ABOVE 32F (DAYS)	22.	29.	31.	30.	22.
DAYS ABOVE 28F (DAYS)	26.	30.	31.	31.	26.
DEG DAYS ABOVE 32F (F)	533.	724.	879.	822.	519.
POT. EVAPOTRANS. (IN)	2.9	4.0	4.6	4.0	2.4
WATER DEFICIENCY (IN)	0.0	0.7	1.6	2.0	1.2
FROST-FREE PERIOD (DAYS)	94.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.3	2.3	2.5	2.0	1.0
MIN. TEMPERATURE (F)	36.5	43.6	47.7	46.0	37.3
DAYS ABOVE 42F (DAYS)	7.	17.	26.	23.	9.
DEG DAYS ABOVE 28F (F)	655.	844.	1003.	946.	639.
DEG DAYS ABOVE 42F (F)	248.	424.	569.	513.	242.
ACT. EVAPOTRANS. (IN)	2.9	3.3	3.0	2.0	1.2
DAY - LENGTH (HRS)	16.1	17.3	16.7	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	114.				

CLIMATIC REGION 3

SALT PRAIRIE LOOKOUT

ELEVATION 2350 FEET LONGITUDE 55 40 3 LATITUDE 115 50 16

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	45.8	52.0	56.6	53.9	43.3
MAX. TEMPERATURE (F)	56.9	63.3	68.2	64.9	53.8
DAYS ABOVE 32F (DAYS)	21.	28.	31.	31.	22.
DAYS ABOVE 28F (DAYS)	27.	30.	31.	31.	26.
DEG DAYS ABOVE 32F (F)	433.	602.	763.	681.	418.
POT. EVAPOTRANS. (IN)	2.8	3.8	4.4	3.7	2.2
WATER DEFICIENCY (IN)	0.0	0.4	1.0	0.8	0.8
FROST-FREE PERIOD (DAYS)	96.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.4	3.2	4.0	2.9	1.3
MIN. TEMPERATURE (F)	35.3	41.3	45.5	43.5	35.8
DAYS ABOVE 42F (DAYS)	5.	11.	20.	17.	5.
DEG DAYS ABOVE 28F (F)	554.	722.	887.	805.	534.
DEG DAYS ABOVE 42F (F)	167.	307.	453.	375.	161.
ACT. EVAPOTRANS. (IN)	2.8	3.4	3.4	2.9	1.4
DAY - LENGTH (HRS)	16.1	17.3	16.7	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	130.				

CLIMATIC REGION 3

SLAVE LAKE

ELEVATION 1920 FEET LONGITUDE 55 17 0 LATITUDE 114 46 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	47.8	53.7	58.2	56.9	48.7
MAX. TEMPERATURE (F)	60.8	67.2	70.4	68.8	56.1
DAYS ABOVE 32F (DAYS)	20.	27.	30.	31.	23.
DAYS ABOVE 28F (DAYS)	26.	28.	30.	31.	27.
DEG DAYS ABOVE 32F (F)	495.	653.	820.	772.	502.
POT. EVAPOTRANS. (IN)	2.8	4.0	4.7	4.0	2.3
WATER DEFICIENCY (IN)	0.0	0.1	0.8	1.4	0.4
FROST-FREE PERIOD (DAYS)	100.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.8	3.5	2.6	2.1	1.8
MIN. TEMPERATURE (F)	35.4	40.7	46.5	45.6	37.8
DAYS ABOVE 42F (DAYS)	5.	16.	25.	22.	8.
DEG DAYS ABOVE 28F (F)	617.	772.	942.	896.	621.
DEG DAYS ABOVE 42F (F)	210.	367.	517.	463.	224.
ACT. EVAPOTRANS. (IN)	2.8	3.9	3.9	2.6	1.9
DAY - LENGTH (HRS)	16.0	17.2	16.6	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	132.				

CLIMATIC REGION 3

WABASCA RS

ELEVATION 1787 FEET LONGITUDE 55 58 0 LATITUDE 113 50 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.7	55.1	59.7	58.1	46.1
MAX. TEMPERATURE (F)	60.8	67.6	70.9	68.9	60.3
DAYS ABOVE 32F (DAYS)	22.	28.	30.	31.	24.
DAYS ABOVE 28F (DAYS)	26.	28.	30.	31.	27.
DEG DAYS ABOVE 32F (F)	524.	694.	866.	810.	519.
POT. EVAPOTRANS. (IN)	2.9	4.0	4.8	4.2	2.4
WATER DEFICIENCY (IN)	0.0	0.2	1.6	2.4	1.4
FROST-FREE PERIOD (DAYS)	105.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.8	2.2	2.9	1.4	1.0
MIN. TEMPERATURE (F)	37.3	43.2	49.1	47.7	36.6
DAYS ABOVE 42F (DAYS)	9.	19.	27.	25.	10.
DEG DAYS ABOVE 28F (F)	646.	813.	988.	933.	638.
DEG DAYS ABOVE 42F (F)	243.	403.	562.	501.	244.
ACT. EVAPOTRANS. (IN)	2.9	3.8	3.2	1.8	1.0
DAY - LENGTH (HRS)	16.1	17.3	16.8	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	132.				

CLIMATIC REGION 3

WAGNER

ELEVATION 1915 FEET LONGITUDE 55 21 0 LATITUDE 114 59 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	46.7	54.4	59.9	57.8	48.7
MAX. TEMPERATURE (F)	58.7	65.5	70.7	68.3	58.7
DAYS ABOVE 32F (DAYS)	20.	29.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	25.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	459.	672.	866.	799.	503.
POT. EVAPOTRANS. (IN)	2.7	3.9	4.7	4.0	2.4
WATER DEFICIENCY (IN)	0.0	0.2	1.1	1.1	0.9
FROST-FREE PERIOD (DAYS)	100.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.7	2.8	3.0	2.6	1.5
MIN. TEMPERATURE (F)	35.1	43.9	49.6	47.7	39.3
DAYS ABOVE 42F (DAYS)	5.	17.	28.	26.	9.
DEG DAYS ABOVE 28F (F)	580.	792.	990.	923.	622.
DEG DAYS ABOVE 42F (F)	184.	372.	556.	489.	224.
ACT. EVAPOTRANS. (IN)	2.7	3.7	3.6	2.9	1.5
DAY - LENGTH (HRS)	16.0	17.2	16.6	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	132.				

CLIMATIC REGION 4

BALD MOUNTAIN LOOKOUT

ELEVATION 3150 FEET | LONGITUDE 54 48 45 | LATITUDE 118 54 50

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	47.7	54.8	59.2	57.3	48.4
MAX. TEMPERATURE (F)	57.0	63.9	68.6	66.4	57.4
DAYS ABOVE 32F (DAYS)	25.	30.	31.	31.	25.
DAYS ABOVE 28F (DAYS)	29.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	488.	684.	844.	784.	494.
POT. EVAPOTRANS. (IN)	2.8	3.9	4.6	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.0	1.3	0.6	0.4
FROST-FREE PERIOD (DAYS)	121.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.3	3.6	2.8	3.6	2.1
MIN. TEMPERATURE (F)	38.8	46.1	50.4	48.7	39.9
DAYS ABOVE 42F (DAYS)	10.	22.	29.	27.	11.
DEG DAYS ABOVE 28F (F)	611.	804.	968.	908.	612.
DEG DAYS ABOVE 42F (F)	209.	384.	534.	475.	221.
ACT. EVAPOTRANS. (IN)	2.8	3.9	3.3	3.3	1.9
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	146.				

CLIMATIC REGION 4

ECONOMY LOOKOUT

ELEVATION 2800 FEET | LONGITUDE 54 47 20 | LATITUDE 118 14 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.3	54.7	59.0	57.2	49.1
MAX. TEMPERATURE (F)	58.7	65.1	69.8	67.5	59.0
DAYS ABOVE 32F (DAYS)	25.	30.	31.	31.	25.
DAYS ABOVE 28F (DAYS)	29.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	509.	682.	838.	781.	516.
POT. EVAPOTRANS. (IN)	2.9	3.9	4.5	3.9	2.4
WATER DEFICIENCY (IN)	0.0	0.1	0.6	0.6	0.5
FROST-FREE PERIOD (DAYS)	126.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.2	3.5	3.4	3.4	1.9
MIN. TEMPERATURE (F)	38.4	44.9	48.8	47.4	39.7
DAYS ABOVE 42F (DAYS)	9.	20.	29.	26.	11.
DEG DAYS ABOVE 28F (F)	631.	802.	962.	905.	635.
DEG DAYS ABOVE 42F (F)	225.	383.	528.	471.	240.
ACT. EVAPOTRANS. (IN)	2.9	3.8	3.9	3.3	1.9
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	146.				

CLIMATIC REGION 4

PUSKWASKAU

ELEVATION 2950 FEET | LONGITUDE 55 13 10 | LATITUDE 117 29 30

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.4	54.4	58.4	56.4	46.8
MAX. TEMPERATURE (F)	57.5	63.8	68.3	65.5	54.7
DAYS ABOVE 32F (DAYS)	26.	30.	31.	31.	26.
DAYS ABOVE 28F (DAYS)	30.	30.	31.	31.	29.
DEG DAYS ABOVE 32F (F)	511.	671.	817.	757.	505.
POT. EVAPOTRANS. (IN)	2.9	3.9	4.5	3.8	2.4
WATER DEFICIENCY (IN)	0.1	0.4	0.7	0.7	0.6
FROST-FREE PERIOD (DAYS)	122.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.9	3.4	3.1	3.1	1.4
MIN. TEMPERATURE (F)	39.8	45.4	48.9	47.8	39.5
DAYS ABOVE 42F (DAYS)	10.	21.	28.	26.	12.
DEG DAYS ABOVE 28F (F)	633.	791.	941.	881.	623.
DEG DAYS ABOVE 42F (F)	228.	373.	507.	449.	231.
ACT. EVAPOTRANS. (IN)	2.9	3.5	3.8	3.1	1.8
DAY - LENGTH (HRS)	16.0	17.2	16.6	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	153.				

CLIMATIC REGION 4

SNUFF MOUNTAIN LOOK.

ELEVATION 3050 FEET | LONGITUDE 54 40 40 | LATITUDE 117 32 1

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	47.6	54.1	58.2	56.6	48.2
MAX. TEMPERATURE (F)	56.4	62.7	66.9	65.1	56.8
DAYS ABOVE 32F (DAYS)	26.	30.	31.	31.	26.
DAYS ABOVE 28F (DAYS)	30.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	485.	665.	811.	762.	490.
POT. EVAPOTRANS. (IN)	2.8	3.9	4.5	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.4	0.7	0.9	0.6
FROST-FREE PERIOD (DAYS)	129.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.3	3.4	2.9	3.1	1.8
MIN. TEMPERATURE (F)	39.2	46.1	50.0	48.6	40.2
DAYS ABOVE 42F (DAYS)	11.	22.	29.	28.	12.
DEG DAYS ABOVE 28F (F)	607.	785.	935.	886.	608.
DEG DAYS ABOVE 42F (F)	206.	365.	501.	452.	217.
ACT. EVAPOTRANS. (IN)	2.8	3.5	3.8	3.0	1.7
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	151.				

CLIMATIC REGION 4

SWEATHOUSE LOOKOUT

ELEVATION 2900 FEET | LONGITUDE 54 55 3 | LATITUDE 116 45 6

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.3	54.2	58.4	56.3	48.4
MAX. TEMPERATURE (F)	58.3	64.7	69.6	66.6	57.7
DAYS ABOVE 32F (DAYS)	26.	30.	31.	31.	26.
DAYS ABOVE 28F (DAYS)	30.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	509.	666.	818.	753.	494.
POT. EVAPOTRANS. (IN)	2.9	3.8	4.5	3.8	2.3
WATER DEFICIENCY (IN)	0.2	0.2	0.6	0.5	0.2
FROST-FREE PERIOD (DAYS)	121.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.2	3.3	4.1	3.7	1.8
MIN. TEMPERATURE (F)	38.8	44.2	47.7	46.5	39.6
DAYS ABOVE 42F (DAYS)	9.	20.	27.	25.	11.
DEG DAYS ABOVE 28F (F)	632.	786.	942.	877.	612.
DEG DAYS ABOVE 42F (F)	224.	367.	508.	444.	219.
ACT. EVAPOTRANS. (IN)	2.9	3.6	3.9	3.3	2.1
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	151.				

CLIMATIC REGION 5

CALMAR

ELEVATION 2200 FEET   LONGITUDE 53 15 0   LATITUDE 113 50 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	50.0	56.8	61.4	59.0	50.3
MAX. TEMPERATURE (F)	63.3	69.5	74.5	71.7	62.7
DAYS ABOVE 32F (DAYS)	23.	30.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	559.	744.	913.	838.	551.
POT. EVAPOTRANS. (IN)	3.0	4.1	4.8	4.1	2.4
WATER DEFICIENCY (IN)	0.0	0.6	1.7	1.6	1.0
FROST-FREE PERIOD (DAYS)	109.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.6	2.5	2.5	2.6	1.5
MIN. TEMPERATURE (F)	37.1	44.7	48.9	46.9	38.5
DAYS ABOVE 42F (DAYS)	8.	19.	27.	25.	8.
DEG DAYS ABOVE 28F (F)	681.	864.	1037.	962.	670.
DEG DAYS ABOVE 42F (F)	257.	444.	603.	529.	269.
ACT. EVAPOTRANS. (IN)	3.0	3.5	3.1	2.5	1.4
DAY - LENGTH (HRS)	15.7	16.5	16.2	14.5	12.5
KILLING FROST-FREE PERIOD (DAYS)	134.				

CLIMATIC REGION 5

THORSBY

ELEVATION 2450 FEET   LONGITUDE 53 14 0   LATITUDE 114 2 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.8	56.1	60.5	58.3	49.6
MAX. TEMPERATURE (F)	62.7	68.5	73.6	70.9	61.6
DAYS ABOVE 32F (DAYS)	24.	30.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	555.	724.	884.	815.	531.
POT. EVAPOTRANS. (IN)	3.0	3.9	4.7	4.0	2.4
WATER DEFICIENCY (IN)	0.0	0.3	1.2	1.7	0.4
FROST-FREE PERIOD (DAYS)	99.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.0	2.5	2.8	2.8	2.3
MIN. TEMPERATURE (F)	37.5	44.2	48.0	46.2	38.2
DAYS ABOVE 42F (DAYS)	8.	21.	28.	25.	9.
DEG DAYS ABOVE 28F (F)	678.	844.	1008.	939.	650.
DEG DAYS ABOVE 42F (F)	266.	424.	574.	505.	254.
ACT. EVAPOTRANS. (IN)	3.0	3.6	3.5	2.3	2.0
DAY - LENGTH (HRS)	15.7	16.5	16.2	14.5	12.5
KILLING FROST-FREE PERIOD (DAYS)	133.				

CLIMATIC REGION 6

VERMILION A

ELEVATION 2037 FEET   LONGITUDE 53 21 0   LATITUDE 110 50 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.7	56.8	62.0	59.4	49.6
MAX. TEMPERATURE (F)	63.2	69.4	75.1	72.0	61.7
DAYS ABOVE 32F (DAYS)	22.	29.	31.	31.	23.
DAYS ABOVE 28F (DAYS)	26.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	552.	745.	929.	851.	530.
POT. EVAPOTRANS. (IN)	3.0	4.1	4.8	4.1	2.3
WATER DEFICIENCY (IN)	0.0	0.5	1.7	1.2	0.9
FROST-FREE PERIOD (DAYS)	94.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.4	2.7	2.1	3.1	1.5
MIN. TEMPERATURE (F)	36.8	44.7	49.3	47.4	38.0
DAYS ABOVE 42F (DAYS)	7.	20.	27.	25.	9.
DEG DAYS ABOVE 28F (F)	674.	865.	1053.	975.	648.
DEG DAYS ABOVE 42F (F)	265.	445.	619.	541.	254.
ACT. EVAPOTRANS. (IN)	3.0	3.6	3.1	2.9	1.4
DAY - LENGTH (HRS)	15.7	16.6	16.2	14.5	12.5
KILLING FROST-FREE PERIOD (DAYS)	119.				

CLIMATIC REGION 7

BEAVERLODGE

ELEVATION 2500 FEET   LONGITUDE 55 11 0   LATITUDE 119 22 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.1	55.1	59.6	57.7	49.1
MAX. TEMPERATURE (F)	59.5	66.7	71.6	69.5	60.0
DAYS ABOVE 32F (DAYS)	23.	30.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	502.	692.	855.	797.	514.
POT. EVAPOTRANS. (IN)	2.8	3.9	4.6	4.0	2.4
WATER DEFICIENCY (IN)	0.0	0.2	1.4	2.6	1.1
FROST-FREE PERIOD (DAYS)	110.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.6	2.9	2.4	2.6	1.3
MIN. TEMPERATURE (F)	37.1	44.0	48.0	46.4	38.6
DAYS ABOVE 42F (DAYS)	8.	18.	27.	23.	9.
DEG DAYS ABOVE 28F (F)	624.	812.	979.	921.	632.
DEG DAYS ABOVE 42F (F)	220.	392.	546.	487.	236.
ACT. EVAPOTRANS. (IN)	2.8	3.7	3.2	2.4	1.3
DAY - LENGTH (HRS)	16.0	17.2	16.6	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	135.				

CLIMATIC REGION 7

DOUCETTE LOOKOUT

ELEVATION 2000 FEET   LONGITUDE 55 49 0   LATITUDE 114 16 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	43.3	55.4	59.8	57.1	45.9
MAX. TEMPERATURE (F)	59.1	66.1	70.9	67.5	56.2
DAYS ABOVE 32F (DAYS)	23.	30.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	510.	703.	960.	777.	497.
POT. EVAPOTRANS. (IN)	2.8	4.0	4.7	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.3	0.2	0.7	0.5
FROST-FREE PERIOD (DAYS)	109.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.0	3.1	4.2	3.0	1.4
MIN. TEMPERATURE (F)	37.9	45.2	49.1	47.2	38.7
DAYS ABOVE 42F (DAYS)	10.	21.	29.	26.	10.
DEG DAYS ABOVE 28F (F)	630.	823.	984.	901.	615.
DEG DAYS ABOVE 42F (F)	232.	404.	550.	469.	227.
ACT. EVAPOTRANS. (IN)	2.8	3.7	4.5	3.2	1.7
DAY - LENGTH (HRS)	16.1	17.3	16.7	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	135.				

CLIMATIC REGION 7

GRAND PRAIRIE A

ELEVATION 2190 FEET   LONGITUDE 55 11 0   LATITUDE 118 53 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.2	56.3	60.9	58.9	49.7
MAX. TEMPERATURE (F)	60.9	67.9	72.5	70.5	61.1
DAYS ABOVE 32F (DAYS)	24.	30.	31.	31.	25.
DAYS ABOVE 28F (DAYS)	29.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	535.	730.	894.	832.	531.
POT. EVAPOTRANS. (IN)	2.9	4.0	4.7	4.0	2.4
WATER DEFICIENCY (IN)	0.0	0.3	0.6	1.4	1.2
FROST-FREE PERIOD (DAYS)	120.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.5	3.0	2.4	2.4	1.2
MIN. TEMPERATURE (F)	38.0	45.3	49.7	47.7	38.7
DAYS ABOVE 42F (DAYS)	8.	21.	29.	26.	9.
DEG DAYS ABOVE 28F (F)	657.	850.	1018.	956.	650.
DEG DAYS ABOVE 42F (F)	247.	430.	584.	522.	252.
ACT. EVAPOTRANS. (IN)	2.9	3.7	3.3	2.6	1.2
DAY - LENGTH (HRS)	16.0	17.2	16.6	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	139.				

CLIMATIC REGION 7

FAIRVIEW

ELEVATION 2160 FEET   LONGITUDE 56 4 0   LATITUDE 118 23 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.6	56.9	61.2	59.0	49.8
MAX. TEMPERATURE (F)	60.8	68.2	72.5	70.1	60.4
DAYS ABOVE 32F (DAYS)	25.	30.	31.	31.	25.
DAYS ABOVE 28F (DAYS)	29.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	547.	746.	905.	836.	533.
POT. EVAPOTRANS. (IN)	2.9	4.1	4.8	4.0	2.3
WATER DEFICIENCY (IN)	0.0	0.6	1.3	1.9	1.1
FROST-FREE PERIOD (DAYS)	122.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.5	2.4	3.0	1.9	0.9
MIN. TEMPERATURE (F)	38.8	46.1	50.4	48.3	39.5
DAYS ABOVE 42F (DAYS)	9.	22.	30.	27.	11.
DEG DAYS ABOVE 28F (F)	669.	866.	1029.	960.	652.
DEG DAYS ABOVE 42F (F)	259.	446.	595.	526.	256.
ACT. EVAPOTRANS. (IN)	2.9	3.5	3.5	2.1	1.2
DAY - LENGTH (HRS)	16.2	17.3	16.8	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	146.				

CLIMATIC REGION 8

MEANOOK

ELEVATION 2250 FEET   LONGITUDE 54 37 0   LATITUDE 113 21 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.5	54.4	58.1	59.2	49.8
MAX. TEMPERATURE (F)	58.7	64.4	67.3	69.2	58.8
DAYS ABOVE 32F (DAYS)	25.	29.	29.	31.	26.
DAYS ABOVE 28F (DAYS)	28.	29.	29.	31.	28.
DEG DAYS ABOVE 32F (F)	536.	704.	856.	846.	536.
POT. EVAPOTRANS. (IN)	2.8	3.8	4.7	4.1	2.4
WATER DEFICIENCY (IN)	0.0	0.2	1.0	0.9	0.7
FROST-FREE PERIOD (DAYS)	121.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.8	3.2	2.8	3.1	1.8
MIN. TEMPERATURE (F)	38.7	45.0	49.3	49.8	41.3
DAYS ABOVE 42F (DAYS)	12.	23.	29.	28.	15.
DEG DAYS ABOVE 28F (F)	654.	819.	972.	970.	655.
DEG DAYS ABOVE 42F (F)	260.	418.	568.	537.	260.
ACT. EVAPOTRANS. (IN)	2.8	3.6	3.7	3.2	1.7
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	148.				

CLIMATIC REGION 9

COLD LAKE A

ELEVATION 1784 FEET   LONGITUDE 54 25 0   LATITUDE 110 17 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.8	57.6	62.7	59.8	49.6
MAX. TEMPERATURE (F)	61.6	68.9	73.7	70.5	60.1
DAYS ABOVE 32F (DAYS)	25.	30.	31.	31.	25.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	553.	768.	950.	863.	530.
POT. EVAPOTRANS. (IN)	2.9	4.2	4.9	4.1	2.3
WATER DEFICIENCY (IN)	0.0	0.6	1.3	1.3	0.7
FROST-FREE PERIOD (DAYS)	98.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.5	2.7	3.2	3.0	1.7
MIN. TEMPERATURE (F)	38.4	46.8	52.0	49.7	39.7
DAYS ABOVE 42F (DAYS)	9.	23.	30.	28.	11.
DEG DAYS ABOVE 28F (F)	676.	888.	1074.	987.	649.
DEG DAYS ABOVE 42F (F)	266.	468.	640.	553.	253.
ACT. EVAPOTRANS. (IN)	2.9	3.8	3.6	2.8	1.6
DAY - LENGTH (HRS)	15.9	17.0	16.4	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	137.				

CLIMATIC REGION 9

IRON RIVER

ELEVATION 1900 FEET   LONGITUDE 54 25 0   LATITUDE 111 0 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.5	56.9	62.1	55.1	49.3
MAX. TEMPERATURE (F)	62.7	69.3	74.4	71.4	61.1
DAYS ABOVE 32F (DAYS)	23.	30.	31.	31.	23.
DAYS ABOVE 28F (DAYS)	26.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	546.	746.	933.	840.	519.
POT. EVAPOTRANS. (IN)	3.0	4.0	4.9	4.0	2.3
WATER DEFICIENCY (IN)	0.0	0.6	1.5	1.5	0.7
FROST-FREE PERIOD (DAYS)	104.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.6	2.6	2.9	2.6	1.6
MIN. TEMPERATURE (F)	37.0	44.9	50.3	47.2	37.9
DAYS ABOVE 42F (DAYS)	8.	21.	29.	25.	8.
DEG DAYS ABOVE 28F (F)	668.	866.	1057.	964.	638.
DEG DAYS ABOVE 42F (F)	257.	446.	623.	530.	241.
ACT. EVAPOTRANS. (IN)	3.0	3.4	3.4	2.5	1.6
DAY - LENGTH (HRS)	15.9	17.0	16.4	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	127.				

CLIMATIC REGION 9

LAC LA BICHE

ELEVATION 1835 FEET   LONGITUDE 54 46 0   LATITUDE 111 58 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.1	56.6	61.7	59.3	47.3
MAX. TEMPERATURE (F)	61.1	68.2	73.1	70.5	59.9
DAYS ABOVE 32F (DAYS)	23.	29.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	27.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	541.	744.	942.	849.	529.
POT. EVAPOTRANS. (IN)	2.9	4.1	4.8	4.1	2.3
WATER DEFICIENCY (IN)	0.0	0.5	1.0	1.3	0.6
FROST-FREE PERIOD (DAYS)	104.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.5	2.7	3.2	2.9	1.9
MIN. TEMPERATURE (F)	37.5	45.5	50.8	48.6	39.1
DAYS ABOVE 42F (DAYS)	8.	21.	29.	26.	10.
DEG DAYS ABOVE 28F (F)	663.	364.	1066.	973.	649.
DEG DAYS ABOVE 42F (F)	258.	444.	632.	539.	252.
ACT. EVAPOTRANS. (IN)	2.9	3.6	3.8	2.8	1.7
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	134.				

CLIMATIC REGION 10

DEER MOUNTAIN LOOKOUT

ELEVATION 3680 FEET   LONGITUDE 54 55 0   LATITUDE 115 9 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	45.8	52.8	57.2	55.0	46.8
MAX. TEMPERATURE (F)	54.9	62.0	67.0	63.9	54.7
DAYS ABOVE 32F (DAYS)	23.	29.	31.	31.	25.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	436.	623.	780.	713.	447.
POT. EVAPOTRANS. (IN)	2.4	3.7	4.4	3.8	2.3
WATER DEFICIENCY (IN)	0.0	0.0	0.2	0.4	0.3
FROST-FREE PERIOD (DAYS)	109.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	3.2	3.7	4.6	4.3	2.0
MIN. TEMPERATURE (F)	37.3	44.1	47.8	46.6	39.4
DAYS ABOVE 42F (DAYS)	8.	19.	27.	25.	11.
DEG DAYS ABOVE 28F (F)	555.	743.	904.	837.	565.
DEG DAYS ABOVE 42F (F)	169.	326.	470.	404.	185.
ACT. EVAPOTRANS. (IN)	2.4	3.7	4.2	3.4	2.0
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	140.				

CLIMATIC REGION 10

HOUSE MOUNTAIN LO.

ELEVATION 3850 FEET   LONGITUDE 55 2 12   LATITUDE 115 36 50

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	46.3	52.8	57.1	55.0	46.7
MAX. TEMPERATURE (F)	55.2	62.0	66.9	63.7	54.5
DAYS ABOVE 32F (DAYS)	24.	29.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	447.	625.	780.	711.	444.
POT. EVAPOTRANS. (IN)	2.6	3.8	4.4	3.8	2.2
WATER DEFICIENCY (IN)	0.0	0.0	0.1	0.4	0.3
FROST-FREE PERIOD (DAYS)	104.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.5	4.3	4.2	3.9	2.1
MIN. TEMPERATURE (F)	37.9	44.3	47.9	46.7	39.3
DAYS ABOVE 42F (DAYS)	9.	20.	27.	24.	10.
DEG DAYS ABOVE 28F (F)	568.	745.	904.	835.	562.
DEG DAYS ABOVE 42F (F)	176.	328.	470.	403.	181.
ACT. EVAPOTRANS. (IN)	2.6	3.8	4.3	3.4	1.9
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	141.				

CLIMATIC REGION 10

HEART LAKE LOOKOUT

ELEVATION 2910 FEET   LONGITUDE 55 0 15   LATITUDE 111 20 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	46.1	52.9	57.1	56.1	46.5
MAX. TEMPERATURE (F)	56.0	62.2	66.0	64.7	54.6
DAYS ABOVE 32F (DAYS)	22.	28.	29.	31.	23.
DAYS ABOVE 28F (DAYS)	26.	29.	29.	31.	27.
DEG DAYS ABOVE 32F (F)	443.	628.	781.	748.	438.
POT. EVAPOTRANS. (IN)	2.7	3.8	4.4	3.9	2.2
WATER DEFICIENCY (IN)	0.0	0.0	0.3	0.3	0.3
FROST-FREE PERIOD (DAYS)	105.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.1	3.9	4.4	3.9	3.0
MIN. TEMPERATURE (F)	36.7	44.1	48.7	48.0	38.9
DAYS ABOVE 42F (DAYS)	8.	20.	28.	26.	10.
DEG DAYS ABOVE 28F (F)	562.	747.	902.	872.	555.
DEG DAYS ABOVE 42F (F)	184.	337.	435.	440.	186.
ACT. EVAPOTRANS. (IN)	2.7	3.8	4.1	3.6	1.9
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	126.				

CLIMATIC REGION 10

KAKUA LOOKOUT

ELEVATION 4050 FEET   LONGITUDE 54 25 30   LATITUDE 118 58 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	45.1	51.8	56.5	54.7	46.3
MAX. TEMPERATURE (F)	54.7	61.6	66.7	64.6	55.7
DAYS ABOVE 32F (DAYS)	22.	30.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	412.	595.	761.	704.	433.
POT. EVAPOTRANS. (IN)	2.7	3.7	4.4	3.8	2.3
WATER DEFICIENCY (IN)	0.0	0.0	0.3	0.8	0.4
FROST-FREE PERIOD (DAYS)	103.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.7	4.3	3.2	4.0	2.2
MIN. TEMPERATURE (F)	36.0	42.5	46.8	45.3	37.3
DAYS ABOVE 42F (DAYS)	5.	15.	26.	23.	7.
DEG DAYS ABOVE 28F (F)	533.	715.	885.	828.	550.
DEG DAYS ABOVE 42F (F)	151.	297.	451.	396.	172.
ACT. EVAPOTRANS. (IN)	2.7	3.7	4.1	3.0	1.9
DAY - LENGTH (HRS)	15.9	17.0	16.4	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	134.				

CLIMATIC REGION 10

MARTEN MOUNTAIN LO.

ELEVATION 3350 FEET LONGITUDE 55 29 30 LATITUDE 114 41 19

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	45.9	52.8	57.1	54.7	46.3
MAX. TEMPERATURE (F)	54.5	60.8	65.0	62.0	53.7
DAYS ABOVE 32F (DAYS)	23.	30.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	27.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	436.	626.	778.	705.	432.
POT. EVAPOTRANS. (IN)	2.6	3.8	4.5	3.8	2.2
WATER DEFICIENCY (IN)	0.0	0.1	0.2	0.6	0.2
FROST-FREE PERIOD (DAYS)	110.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.9	3.8	4.1	3.6	1.9
MIN. TEMPERATURE (F)	37.7	45.4	49.6	47.9	39.4
DAYS ABOVE 42F (DAYS)	9.	21.	29.	27.	10.
DEG DAYS ABOVE 28F (F)	556.	746.	902.	829.	550.
DEG DAYS ABOVE 42F (F)	172.	329.	468.	398.	175.
ACT. EVAPOTRANS. (IN)	2.6	3.7	4.3	3.2	1.9
DAY - LENGTH (HRS)	16.0	17.2	16.7	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	134.				

CLIMATIC REGION 10

PELICAN MOUNTAIN LO.

ELEVATION 3000 FEET LONGITUDE 55 37 0 LATITUDE 113 34 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	47.1	53.6	58.1	55.2	44.9
MAX. TEMPERATURE (F)	56.7	63.4	68.3	64.8	53.6
DAYS ABOVE 32F (DAYS)	25.	30.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	29.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	471.	647.	809.	720.	456.
POT. EVAPOTRANS. (IN)	2.8	3.8	4.5	3.8	2.3
WATER DEFICIENCY (IN)	0.0	0.2	0.3	0.7	0.4
FROST-FREE PERIOD (DAYS)	110.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.5	4.1	3.9	3.1	2.3
MIN. TEMPERATURE (F)	38.0	44.2	48.4	46.1	36.7
DAYS ABOVE 42F (DAYS)	8.	19.	28.	25.	9.
DEG DAYS ABOVE 28F (F)	593.	767.	933.	843.	574.
DEG DAYS ABOVE 42F (F)	198.	350.	499.	413.	196.
ACT. EVAPOTRANS. (IN)	2.8	3.6	4.2	3.1	1.9
DAY - LENGTH (HRS)	16.1	17.3	16.7	14.8	12.5
KILLING FROST-FREE PERIOD (DAYS)	141.				

CLIMATIC REGION 10

PIMPLE LOOKOUT

ELEVATION 3619 FEET LONGITUDE 54 29 45 LATITUDE 115 27 50

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	46.3	52.2	56.7	54.6	46.7
MAX. TEMPERATURE (F)	55.0	61.2	66.2	63.3	54.6
DAYS ABOVE 32F (DAYS)	25.	30.	31.	31.	25.
DAYS ABOVE 28F (DAYS)	29.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	446.	607.	766.	700.	444.
POT. EVAPOTRANS. (IN)	2.7	3.7	4.4	3.8	2.2
WATER DEFICIENCY (IN)	0.0	0.1	0.5	0.6	0.9
FROST-FREE PERIOD (DAYS)	112.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.1	3.6	3.7	3.3	1.2
MIN. TEMPERATURE (F)	38.0	43.8	47.7	46.3	39.3
DAYS ABOVE 42F (DAYS)	8.	18.	26.	24.	10.
DEG DAYS ABOVE 28F (F)	568.	727.	890.	824.	562.
DEG DAYS ABOVE 42F (F)	171.	309.	456.	391.	177.
ACT. EVAPOTRANS. (IN)	2.7	3.6	3.9	3.2	1.8
DAY - LENGTH (HRS)	15.9	17.0	16.4	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	143.				

CLIMATIC REGION 10

SWAN DIVE LOOKOUT

ELEVATION 4174 FEET LONGITUDE 54 43 38 LATITUDE 115 13 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	45.7	52.5	57.4	55.1	46.2
MAX. TEMPERATURE (F)	54.2	61.7	66.9	63.6	54.0
DAYS ABOVE 32F (DAYS)	25.	29.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	428.	616.	789.	715.	431.
POT. EVAPOTRANS. (IN)	2.6	3.8	4.4	3.8	2.2
WATER DEFICIENCY (IN)	0.0	0.2	0.2	0.7	0.3
FROST-FREE PERIOD (DAYS)	104.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.5	3.5	4.4	3.8	1.7
MIN. TEMPERATURE (F)	37.7	43.8	48.4	47.0	38.8
DAYS ABOVE 42F (DAYS)	8.	18.	27.	25.	10.
DEG DAYS ABOVE 28F (F)	548.	736.	913.	839.	548.
DEG DAYS ABOVE 42F (F)	166.	319.	479.	406.	177.
ACT. EVAPOTRANS. (IN)	2.6	3.6	4.2	3.1	1.8
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	144.				

CLIMATIC REGION 11

ATHABASCA

ELEVATION 1700 FEET LONGITUDE 54 43 0 LATITUDE 113 17 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.3	54.6	60.2	58.0	48.8
MAX. TEMPERATURE (F)	62.8	69.6	75.2	72.3	62.0
DAYS ABOVE 32F (DAYS)	18.	27.	31.	31.	21.
DAYS ABOVE 28F (DAYS)	24.	29.	31.	31.	27.
DEG DAYS ABOVE 32F (F)	509.	687.	874.	805.	504.
POT. EVAPOTRANS. (IN)	2.9	3.9	4.7	4.0	2.3
WATER DEFICIENCY (IN)	0.0	0.4	1.3	0.9	0.7
FROST-FREE PERIOD (DAYS)	83.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.2	2.9	3.0	3.1	1.5
MIN. TEMPERATURE (F)	34.3	40.1	45.7	44.2	36.0
DAYS ABOVE 42F (DAYS)	4.	10.	22.	19.	6.
DEG DAYS ABOVE 28F (F)	631.	805.	998.	929.	623.
DEG DAYS ABOVE 42F (F)	225.	392.	565.	495.	227.
ACT. EVAPOTRANS. (IN)	2.9	3.5	3.4	3.1	1.6
DAY - LENGTH (HRS)	15.9	17.1	16.5	14.7	12.5
KILLING FROST-FREE PERIOD (DAYS)	115.				

CLIMATIC REGION 11

CAMPSIE

ELEVATION 2200 FEET   LONGITUDE 54 8 0   LATITUDE 114 41 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.8	55.5	60.2	57.6	48.9
MAX. TEMPERATURE (F)	62.5	68.7	73.5	70.5	61.7
DAYS ABOVE 32F (DAYS)	20.	28.	31.	30.	21.
DAYS ABOVE 28F (DAYS)	25.	30.	31.	31.	26.
DEG DAYS ABOVE 32F (F)	523.	705.	878.	797.	508.
POT. EVAPOTRANS. (IN)	2.9	4.0	4.7	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.3	0.9	1.0	0.8
FROST-FREE PERIOD (DAYS)	74.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.6	3.2	2.9	3.2	1.2
MIN. TEMPERATURE (F)	35.7	42.8	47.5	45.1	36.6
DAYS ABOVE 42F (DAYS)	6.	17.	24.	21.	7.
DEG DAYS ABOVE 28F (F)	645.	825.	1001.	920.	628.
DEG DAYS ABOVE 42F (F)	235.	406.	569.	488.	229.
ACT. EVAPOTRANS. (IN)	2.9	3.7	3.8	2.9	1.5
DAY - LENGTH (HRS)	15.8	16.9	16.3	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	113.				

CLIMATIC REGION 11

EDSON

ELEVATION 3033 FEET   LONGITUDE 53 35 0   LATITUDE 116 25 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	47.0	54.0	58.5	56.6	48.3
MAX. TEMPERATURE (F)	60.3	67.4	72.8	70.1	61.5
DAYS ABOVE 32F (DAYS)	18.	27.	30.	30.	21.
DAYS ABOVE 28F (DAYS)	25.	30.	31.	31.	25.
DEG DAYS ABOVE 32F (F)	461.	670.	851.	793.	508.
POT. EVAPOTRANS. (IN)	2.8	3.8	4.5	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.0	0.3	0.5	0.4
FROST-FREE PERIOD (DAYS)	71.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.3	3.2	4.1	3.1	1.7
MIN. TEMPERATURE (F)	34.2	41.1	44.7	43.6	35.6
DAYS ABOVE 42F (DAYS)	4.	13.	22.	18.	5.
DEG DAYS ABOVE 28F (F)	584.	790.	975.	917.	627.
DEG DAYS ABOVE 42F (F)	180.	371.	541.	483.	229.
ACT. EVAPOTRANS. (IN)	2.8	3.8	4.2	3.4	1.9
DAY - LENGTH (HRS)	15.8	16.8	16.2	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	113.				

CLIMATIC REGION 11

ENTRANCE

ELEVATION 3225 FEET   LONGITUDE 53 22 2   LATITUDE 117 43 10

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	46.2	53.0	57.4	55.8	47.5
MAX. TEMPERATURE (F)	59.8	66.6	72.3	70.4	61.2
DAYS ABOVE 32F (DAYS)	16.	27.	30.	30.	18.
DAYS ABOVE 28F (DAYS)	24.	30.	31.	31.	25.
DEG DAYS ABOVE 32F (F)	443.	630.	788.	738.	467.
POT. EVAPOTRANS. (IN)	2.7	3.8	4.5	3.8	2.4
WATER DEFICIENCY (IN)	0.0	0.3	0.7	0.9	0.7
FROST-FREE PERIOD (DAYS)	59.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.2	3.3	2.6	3.3	1.7
MIN. TEMPERATURE (F)	33.1	39.8	43.0	41.7	34.3
DAYS ABOVE 42F (DAYS)	2.	9.	17.	12.	4.
DEG DAYS ABOVE 28F (F)	565.	750.	912.	862.	586.
DEG DAYS ABOVE 42F (F)	165.	330.	481.	429.	193.
ACT. EVAPOTRANS. (IN)	2.7	3.5	3.8	2.9	1.7
DAY - LENGTH (HRS)	15.7	16.7	16.2	14.5	12.5
KILLING FROST-FREE PERIOD (DAYS)	112.				

CLIMATIC REGION 11

HINTON

ELEVATION 3325 FEET   LONGITUDE 53 24 0   LATITUDE 117 33 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	46.9	53.8	58.2	56.4	48.4
MAX. TEMPERATURE (F)	60.5	67.8	73.2	70.7	61.7
DAYS ABOVE 32F (DAYS)	16.	27.	30.	30.	19.
DAYS ABOVE 28F (DAYS)	24.	30.	31.	31.	26.
DEG DAYS ABOVE 32F (F)	462.	653.	813.	757.	493.
POT. EVAPOTRANS. (IN)	2.7	3.8	4.5	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.0	0.7	0.9	0.7
FROST-FREE PERIOD (DAYS)	60.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.5	3.8	2.9	3.5	1.6
MIN. TEMPERATURE (F)	33.7	40.2	43.7	42.7	35.6
DAYS ABOVE 42F (DAYS)	4.	11.	19.	16.	5.
DEG DAYS ABOVE 28F (F)	585.	773.	937.	881.	612.
DEG DAYS ABOVE 42F (F)	181.	353.	506.	448.	217.
ACT. EVAPOTRANS. (IN)	2.7	3.8	3.8	2.8	1.6
DAY - LENGTH (HRS)	15.7	16.7	16.2	14.5	12.5
KILLING FROST-FREE PERIOD (DAYS)	114.				

CLIMATIC REGION 11

NEWBROOK

ELEVATION 2200 FEET   LONGITUDE 54 20 0   LATITUDE 112 57 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.0	54.4	58.2	57.1	47.9
MAX. TEMPERATURE (F)	61.2	67.3	70.7	70.2	60.1
DAYS ABOVE 32F (DAYS)	20.	28.	31.	30.	20.
DAYS ABOVE 28F (DAYS)	26.	30.	31.	31.	26.
DEG DAYS ABOVE 32F (F)	503.	679.	826.	780.	479.
POT. EVAPOTRANS. (IN)	2.9	3.9	4.6	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.3	1.4	0.9	0.7
FROST-FREE PERIOD (DAYS)	75.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.4	2.7	2.7	2.8	1.7
MIN. TEMPERATURE (F)	35.3	42.1	46.3	44.6	36.2
DAYS ABOVE 42F (DAYS)	6.	14.	23.	19.	6.
DEG DAYS ABOVE 28F (F)	624.	798.	947.	904.	597.
DEG DAYS ABOVE 42F (F)	221.	382.	525.	470.	208.
ACT. EVAPOTRANS. (IN)	2.9	3.6	3.2	2.8	1.6
DAY - LENGTH (HRS)	15.8	17.0	16.4	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	114.				

CLIMATIC REGION 11

WHITECOURT

ELEVATION 2430 FEET LONGITUDE 54 8 0 LATITUDE 115 40 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	47.4	54.3	59.2	56.7	47.9
MAX. TEMPERATURE (F)	61.0	67.6	72.8	69.6	60.6
DAYS ABOVE 32F (DAYS)	18.	27.	31.	30.	20.
DAYS ABOVE 28F (DAYS)	24.	29.	31.	31.	25.
DEG DAYS ABOVE 32F (F)	482.	669.	844.	766.	479.
POT. EVAPOTRANS. (IN)	2.8	3.9	4.6	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.0	0.6	1.6	0.7
FROST-FREE PERIOD (DAYS)	77.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	2.2	3.3	3.5	3.5	1.2
MIN. TEMPERATURE (F)	34.3	41.4	46.2	44.3	35.7
DAYS ABOVE 42F (DAYS)	5.	13.	23.	19.	6.
DEG DAYS ABOVE 28F (F)	604.	789.	968.	890.	598.
DEG DAYS ABOVE 42F (F)	199.	370.	534.	456.	205.
ACT. EVAPOTRANS. (IN)	2.8	3.9	4.0	3.3	1.6
DAY - LENGTH (HRS)	15.8	16.9	16.3	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	106.				

CLIMATIC REGION 12

ELK POINT

ELEVATION 1920 FEET LONGITUDE 53 53 0 LATITUDE 110 54 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.0	56.8	61.6	58.9	49.0
MAX. TEMPERATURE (F)	62.2	69.5	74.4	71.5	61.1
DAYS ABOVE 32F (DAYS)	21.	29.	31.	31.	22.
DAYS ABOVE 28F (DAYS)	26.	30.	31.	31.	26.
DEG DAYS ABOVE 32F (F)	534.	743.	920.	835.	513.
POT. EVAPOTRANS. (IN)	2.9	4.0	4.8	4.1	2.4
WATER DEFICIENCY (IN)	0.0	0.5	0.9	1.3	0.6
FROST-FREE PERIOD (DAYS)	98.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.5	2.9	2.9	2.9	1.9
MIN. TEMPERATURE (F)	36.4	44.5	49.4	46.9	37.5
DAYS ABOVE 42F (DAYS)	7.	18.	26.	24.	8.
DEG DAYS ABOVE 28F (F)	656.	863.	1043.	959.	631.
DEG DAYS ABOVE 42F (F)	252.	444.	610.	525.	239.
ACT. EVAPOTRANS. (IN)	2.9	3.5	3.7	2.8	1.8
DAY - LENGTH (HRS)	15.8	16.9	16.3	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	118.				

CLIMATIC REGION 12

ROCHESTER

ELEVATION 2050 FEET LONGITUDE 54 22 0 LATITUDE 113 21 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	48.7	54.1	57.1	57.4	48.3
MAX. TEMPERATURE (F)	61.3	66.4	69.4	69.7	60.4
DAYS ABOVE 32F (DAYS)	22.	28.	29.	31.	22.
DAYS ABOVE 28F (DAYS)	27.	29.	30.	31.	26.
DEG DAYS ABOVE 32F (F)	524.	681.	818.	787.	493.
POT. EVAPOTRANS. (IN)	3.0	3.9	4.7	3.9	2.3
WATER DEFICIENCY (IN)	0.0	0.5	1.1	1.1	0.9
FROST-FREE PERIOD (DAYS)	82.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.7	2.7	2.8	2.8	1.4
MIN. TEMPERATURE (F)	36.6	42.2	45.2	45.5	36.8
DAYS ABOVE 42F (DAYS)	7.	15.	23.	21.	6.
DEG DAYS ABOVE 28F (F)	645.	798.	936.	911.	611.
DEG DAYS ABOVE 42F (F)	239.	388.	523.	478.	222.
ACT. EVAPOTRANS. (IN)	3.0	3.4	3.6	2.8	1.4
DAY - LENGTH (HRS)	15.8	17.0	16.4	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	122.				

CLIMATIC REGION 13

FORT SASKATCHEWAN

ELEVATION 2050 FEET LONGITUDE 53 43 0 LATITUDE 113 10 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	51.3	58.1	62.9	60.6	51.2
MAX. TEMPERATURE (F)	63.7	69.9	75.3	72.2	62.4
DAYS ABOVE 32F (DAYS)	25.	30.	31.	31.	26.
DAYS ABOVE 28F (DAYS)	29.	30.	31.	31.	29.
DEG DAYS ABOVE 32F (F)	600.	784.	958.	886.	576.
POT. EVAPOTRANS. (IN)	3.0	4.2	4.9	4.2	2.4
WATER DEFICIENCY (IN)	0.0	0.8	1.8	1.8	0.6
FROST-FREE PERIOD (DAYS)	116.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.5	2.9	2.2	2.7	2.0
MIN. TEMPERATURE (F)	39.4	46.9	51.0	49.4	40.4
DAYS ABOVE 42F (DAYS)	11.	23.	29.	27.	12.
DEG DAYS ABOVE 28F (F)	723.	904.	1082.	1010.	696.
DEG DAYS ABOVE 42F (F)	307.	484.	648.	576.	293.
ACT. EVAPOTRANS. (IN)	3.0	3.4	3.1	2.4	1.8
DAY - LENGTH (HRS)	15.8	16.8	16.2	14.6	12.5
KILLING FROST-FREE PERIOD (DAYS)	142.				

CLIMATIC REGION 13

RANFURLY

ELEVATION 2250 FEET LONGITUDE 53 27 0 LATITUDE 111 39 0

	MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	50.0	57.0	61.9	59.5	49.7
MAX. TEMPERATURE (F)	62.3	68.6	73.9	70.9	60.6
DAYS ABOVE 32F (DAYS)	24.	30.	31.	31.	24.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	28.
DEG DAYS ABOVE 32F (F)	560.	749.	928.	852.	533.
POT. EVAPOTRANS. (IN)	3.0	4.1	4.8	4.1	2.4
WATER DEFICIENCY (IN)	0.0	0.5	1.3	1.1	0.7
FROST-FREE PERIOD (DAYS)	101.				

	MAY	JUNE	JULY	AUG	SEPT
PRECIPITATION (IN)	1.4	2.7	3.0	3.1	1.7
MIN. TEMPERATURE (F)	38.1	45.8	50.5	48.5	39.3
DAYS ABOVE 42F (DAYS)	9.	22.	29.	27.	10.
DEG DAYS ABOVE 28F (F)	682.	869.	1052.	976.	652.
DEG DAYS ABOVE 42F (F)	272.	449.	618.	542.	260.
ACT. EVAPOTRANS. (IN)	3.0	3.6	3.5	3.0	1.7
DAY - LENGTH (HRS)	15.7	16.7	16.2	14.5	12.5
KILLING FROST-FREE PERIOD (DAYS)	133.				

CLIMATIC REGION 13

SION

ELEVATION 2315 FEET LONGITUDE 53 54 0 LATITUDE 114 8 0

	MAY	JUNE	JULY	AUG	SEPT		MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.7	55.6	60.3	58.0	50.2	PRECIPITATION (IN)	1.4	3.0	2.0	3.1	1.8
MAX. TEMPERATURE (F)	61.4	67.6	72.6	69.4	61.1	MIN. TEMPERATURE (F)	38.4	44.1	48.6	47.0	39.7
DAYS ABOVE 32F (DAYS)	25.	29.	31.	31.	26.	DAYS ABOVE 42F (DAYS)	10.	20.	28.	26.	11.
DAYS ABOVE 28F (DAYS)	29.	30.	31.	31.	29.	DEG DAYS ABOVE 28F (F)	673.	829.	1002.	929.	665.
DEG DAYS ABOVE 32F (F)	550.	709.	878.	805.	545.	DEG DAYS ABOVE 42F (F)	258.	410.	568.	495.	259.
POT. EVAPOTRANS. (IN)	3.1	3.9	4.7	4.0	2.6	ACT. EVAPOTRANS. (IN)	3.1	3.4	3.0	2.9	1.8
WATER DEFICIENCY (IN)	0.0	0.5	1.7	1.1	0.8	DAY - LENGTH (HRS)	15.8	16.9	16.3	14.6	12.5
FROST-FREE PERIOD (DAYS)	114.					KILLING FROST-FREE PERIOD (DAYS)		141.			

CLIMATIC REGION 13

VEGREVILLE

ELEVATION 2082 FEET LONGITUDE 53 29 0 LATITUDE 112 3 0

	MAY	JUNE	JULY	AUG	SEPT		MAY	JUNE	JULY	AUG	SEPT
MEAN TEMPERATURE (F)	49.3	55.5	59.4	58.6	49.0	PRECIPITATION (IN)	1.3	2.6	3.0	2.9	1.5
MAX. TEMPERATURE (F)	63.2	69.4	75.7	72.6	62.3	MIN. TEMPERATURE (F)	38.5	45.3	50.3	48.2	39.1
DAYS ABOVE 32F (DAYS)	25.	29.	31.	31.	24.	DAYS ABOVE 42F (DAYS)	9.	22.	28.	25.	11.
DAYS ABOVE 28F (DAYS)	28.	30.	31.	31.	27.	DEG DAYS ABOVE 28F (F)	664.	825.	973.	948.	634.
DEG DAYS ABOVE 32F (F)	546.	706.	850.	825.	518.	DEG DAYS ABOVE 42F (F)	292.	449.	562.	569.	277.
POT. EVAPOTRANS. (IN)	3.2	4.0	4.6	4.0	2.5	ACT. EVAPOTRANS. (IN)	3.2	3.1	3.0	3.0	1.7
WATER DEFICIENCY (IN)	0.1	0.9	1.6	1.0	0.8	DAY - LENGTH (HRS)	15.7	16.7	16.2	14.5	12.5
FROST-FREE PERIOD (DAYS)	112.					KILLING FROST-FREE PERIOD (DAYS)		139.			

and at Salt Prairie of 52.0°F places these within the same climatic type. The June mean daily temperature of 54.1°F at Snuff Mountain however, is found within a different climatic type. Likewise, the mean June precipitation of 2.8 inches at Wagner and 3.2 inches at Salt Prairie are in a climatically different area than the Snuff Mountain precipitation total of 3.4 inches. Possibly the distinguishing feature between these three stations is found in the frost-free period. Wagner and Salt Prairie have 100 and 96 days respectively, whereas Snuff Mountain is found to have 129 days. But this difference in frost-free days does not hold for all stations. For example, Calmar has 109 days, yet in comparison with Wagner it is climatically different. Therefore, in conclusion, it is the interrelationship among each of these 75 variables which accounts for the thirteen groupings of the 52 stations. For the purpose of detailed interpretation, Table 9.1 is able to supply the precise climatic descriptions of each macroclimatological area. Table 9.1 represents normals per month for each of the respective input variables. The normals, based upon the period between May and September from 1954-1968 provide a climatological base for the forestry towers - not previously available.

The selected "most important" seasonal variables per climatic group are shown in Table 9.2. Again, even with this reduced number of variables, difficulty arises in determining the dominant characteristics per region. Consequently, these seasonal ranges of the variables - and the previous detailed descriptions of each climatic zone provide the required information to satisfy the objectives of this study, as outlined on page 1.

Table 9.2

Selected Seasonal Normals (1 May - 30 September)
1954 - 1968

GROUP NUMBER	TEMPERATURE (°F) MEAN	TEMPERATURE (°F) MAXIMUM	TEMPERATURE (°F) MINIMUM	PRECIPITATION INCHES	DEGREE-DAYS (°F) >28 x 100	DEGREE-DAYS (°F) >32 x 100	DEGREE-DAYS (°F) >42 x 100	POTENTIAL EVAPOTRANSPIRATION INCHES	DAY LENGTH HOURS	FROST-FREE PERIOD DAYS	KILLING FROST-FREE PERIOD DAYS
1	52-54	64-66	42-44	12	40-42	34-36	18-20	18	15.3-15.4	100-120	120-140
2	50-52	58-62	40-42	16-18	32-36	24-28	10-14	15-17	15.1-15.4	80-100	100-140
3	52-54	64-66	40-42	10-12	38	32-34	16-18	17-18	15.4-15.5	80-120	120-140
4	52-54	62-66	40-44	12-16	38-40	32-34	16-20	17-18	15.3-15.4	100-120	140-160
5	54-56	66-70	42-44	10-14	40-44	34-38	20-22	18-20	15.1-15.2	80-120	120-140
6	54-56	68-70	42-44	10-12	42-44	36-38	20-22	18-20	15.1-15.2	80-100	100-120
7	54-56	64-68	44-46	10-12	38-42	34-36	20-22	18-20	15.4-15.5	100-120	120-140
8	52-54	62-64	44-46	12-14	40-42	34-36	20-22	18-20	15.3-15.4	120-140	140-160
9	54-56	66-68	42-46	10-12	40-42	34-38	20-22	18-20	15.3-15.4	80-120	120-140
10	50-52	60-62	42-44	14-18	30-38	26-32	12-18	16-17	15.2-15.4	100-120	140-160
11	52-54	64-66	38-42	12-16	38-40	32-34	18-20	17-18	15.1-15.4	60-100	100-120
12	54-56	66-68	42-44	12-14	38-42	32-36	18-22	17-19	15.2-15.3	80-100	100-140
13	54-58	66-70	42-46	10-12	40-46	34-38	18-24	18-19	15.1-15.2	100-120	120-160

Chapter 10

Discussion of the Results

The previous chapter both defines and describes the climatically similar regions. But what of the associated vegetational and soil characteristics?

Associated Vegetation and Soil Types per Station per Group

No attempt, with the exception of including evapotranspiration estimates, has been made within this thesis to correlate phytobiological-climatic variabilities. The complete understanding of vegetational and soil responses as a function of the climate is not in the author's background nor is it the intention of this study. However, listing of the stations with associated soils and vegetational types is presented in Table 10.1. From this, broad generalizations become apparent. For example, group 2 is characterized by two types of vegetation--AeS and LWe--with one type of soil--grey-wooded. In most cases, the clustering of the groups as either A or L with predominant soil types as either dark-grey--dark-grey-wooded or grey-wooded typifies the climatic groupings. Generally speaking, the occurrence of one climatic type is associated with the predominance of either a vegetational and/or a soil type. Striking examples of this point are illustrated in the climatic grouping of Calmar and Thorsby with an associated unique vegetation A and soil--black. Only one other station--Fort Saskatchewan--has the same type of associated regimes. Yet the proximity of Fort Saskatchewan to the North Saskatchewan River could account for its grouping into another climate. Therefore, usually the anomalies with the generalized

Table 10.1

GROUP NUMBER	STATION	VEGETATION (After Atlas of Alberta)	SOIL* (After Atlas of Alberta)
1	Athabasca 2	A >50%	2
2	Yellowhead	LWE	3
	Goose	AeS	3
	Whitecourt Lo.	AeS	3
	Simonette	LWE	3
3	Rycroft	Ap >50%	5
	Round Hill	Ap >50%	7
	Conklin	A	7
	Wabasca	A	7
	Slave Lake	Ap <50%	2
	Kinuso	Ap <50%	2
	High Prairie	Ap <50%	2
	Falher	Ap >50%	5
	Salt Prairie	A	3
	Wagner	AeS	3
4	Snuff Mtn.	AeS	3
	Sweathouse	A	3
	Puskwaskau	A	3
	Economy	AeS	3
	Bald Mtn.	AeS	3
5	Calmar	A >50%	1
	Thorsby	A >50%	2
6	Vermilion	Ap >50%	1
7	Doucette	A	7
	Grande Prairie	Ap >50%	5
	Beaverlodge	Ap <50%	5
	Fairview	Ap >50%	5
8	Meanook	A <50%	2
9	Iron River	A <50%	3
	Lac La Biche	A <50%	3
	Cold Lake	A <50%	3

Table 10.1 continued

GROUP NUMBER	STATION	VEGETATION (After Atlas of Alberta)	SOIL* (After Atlas of Alberta)
10	Swan Dive	LW	3
	House	LW	3
	Pimple	LW	3
	Marten	LS	3
	Pelican	LS	3
	Heart Lake	A	3
	Kakwa	LW	3
	Deer	LW	3
11	Newbrook	A >50%	2
	Campsie	A >50%	2
	Edson	AeS <50%	7
	Hinton	AeS	3
	Entrance	AeS	3
	Whitecourt	A	3
	Athabasca	A <50%	2
12	Rochester	A <50%	3
	Elk Point	A <50%	2
13	Ranfurly	Ap <50%	2
	Vegreville	Ap >50%	4
	Ft. Saskatchewan	A <50%	4
	Sion	Aes >50%	2

*Soil Groups:

1 - Black
2 - Dark Grey and Dark Grey-Wooded
3 - Grey-Wooded
4 - Black and Solonetzic
5 - Dark Grey and Dark Grey-Wooded and Solonetzic
6 - Grey-Wooded and Solonetzic
7 - Grey-Wooded and Organic
8 - Grey-Wooded and Solonetzic and Organic

vegetational-soil-climatic types can be explained upon investigation of the physical setting of the observing sites.

Evaluation of the Statistical Classification Technique

As was previously stated, the results of the classifications by researchers such as Koeppen, Thornthwaite, Fairbairn and Holderidge failed to supply the amount of detail required to satisfy the objectives of this project. Bowser achieved the best definition of scale but lacked the associated climatic parameter descriptions. The technique, as outlined in this thesis, provides the needed climatic areas on a scale of use to management and research programs.

Consequently, by comparing the statistical zones, derived in this study as outlined in Figure 9.2, with the Bowser results, as shown in Figure 2.5, general areas of similarity appear. Because of the difference in scale, the comparison of the author's results with those of Rheumer, Figure 2.2 and Longley, Figure 2.1, is not particularly rewarding. Bowser in 1967 classified areas such as the foothills, Swan Hills, Pelican Mountain and Conklin areas as 5H. These combinations of letters denote the poorest capability for crop growth where the limiting factor is heat. However, the statistical classification differentiates between Conklin and the foothill regions but does group the Swan Hills and Pelican Mountains as one climatic type. Also, if the Bowser areas labelled 1 and 2H are combined, and the statistical areas 7, 6, 5, and 13 are combined, a general similarity in the climatic patterns results. Elsewhere, discrepancies between the remaining areas result. These differences are to be expected since the Bowser and statistical systems of classification utilize different input

station indices. However, the general correspondence of some areas provides an indicator of the validity of the statistical grouping procedure.

Likewise, the climatic regions as postulated by Chapman and Brown, Figure 2.4, indicate a general agreement in the south-eastern portion of the map with the statistical climatic map. The area denoted by 6F agrees with the statistical region 6. Likewise, 66, 56, and 76 each have somewhat similar boundaries as the climatic regions 13, 5 and 12 respectively. Disagreements in the Peace River Region, in the northwest of the study area, and in the forested areas of the province with the statistical climatic areas are noted. As mentioned previously, this is largely a result of the difference in input variables, years of data and classification techniques. But generally, agreement in certain areas of the above classifications with the statistical classification procedure indicates to some degree the validity of the results.

Consequently, the primary objective of this study has been satisfied--the delineation of homogeneous climatic areas within the study area in northern Alberta. The first secondary objective--to provide a climatic base for the study area--has been outlined and described in Chapter 5. The other secondary objective--evaluation of mobile thermo dew-point recording--has also been described previously in Chapter 7 with application of the technique to the macroclimatic zones being illustrated in Chapter 9. In conclusion, the primary and secondary objectives have been fulfilled--but what of future recommendations?

Recommendations for Further Research

Since the technique has apparently provided the needed answers

within the study area, the one recommendation would involve application of this model to other areas of the province. Prediction equations generated by factor analysis do not require further total reclassification of the entire data base. Only the substitution into the formulae and the subsequent fitting of the station indices within the existing climatic types is necessary to enable further areas to be classified. This would be particularly useful in application to the stations within the study area which were not included in the analysis. The resulting increased density in the reporting network would therefore help considerably in the delineation and placing of the climatic boundaries.

An additional aid to determining the location of the climatic limits is also found in the mobile thermo dew-point recorder. The results obtained have helped considerably both in evaluation of the site of the present observing stations and the variability in temperature under various conditions. However, it would seem that the summer research of 1969 has only "scratched the surface" in the use of this technique. More detailed traverses under a variety of atmospheric conditions over preselected routes should be able to furnish prediction equations for both temperature and dew-point in places where no observing station exists. Application of this method of thermal detection would be extremely valuable in the mountainous areas of Alberta, where the observing stations tend to be rather unique in areal representativeness.

One other area has possibilities for further research--polynomial regression estimation. Each of the estimated values within this thesis is required to conform to a prescribed level of significance (99.9%) and yet better estimation could possibly be obtained through

the use of multi-polynomial regression equations. These equations are multi-polynomial in the sense that instead of simply the squaring of X or Y, the interaction between X and Y in the form XY is also given. Coupled with this is the incorporation of two independent variable stations to be used in order to predict for the third. Consequently, instead of the primary reliance for prediction on one station as a function of another station, the irregularities or anomalies per day could be better smoothed if the one station is a function of two other stations. Familiarity with this type of statistical prediction was not known at the time of analyzing the data for this thesis, but from all appearances, it would seem to provide a better estimating technique.

In conclusion, these are the areas where further research within the classification model might be profitable. None are of an imperative or critical nature such as to affect the present results, yet it is felt that with their application improvement or refinement of the classification could be attained. For the purposes of completing the objectives of this study however, the present classification model has functioned quite satisfactorily.

BIBLIOGRAPHY

Anderson, M. L. and W. A. Fairbairn, 1955: Division of Scotland into Climatic Sub-Regions as an Aid to Silviculture. Bulletin of the Forestry Department, University of Edinburgh, Scotland, 33 p.

Baier, W. and D. A. Russelo, 1968: A Computer Program for Estimating Risks of Irrigation Requirements from Climatic Data. Agrometeorology Section, Plant Research Institute, Canada Department of Agriculture, Tech. Bull. 59, 47 p.

Blalock, H. M., 1960: Social Statistics. McGraw-Hill Book Company, Inc., 465 p.

Bowser, W. E., 1967: Agro-Climatic Areas of Alberta. Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa.

Carter, D. B. and J. R. Mather, 1966: Climatic Classification for Environmental Biology. The Johns Hopkins University Laboratory of Climatology, Publications in Climatology, Vol. XIX, No. 4, p. 305-395.

Chapman, L. J. and D. M. Brown, 1966: The Climates of Canada for Agriculture. Canada Land Inventory, ARDA, Department of Forestry and Rural Development, 23 p.

Djurfors, S. G., 1969: Urban Air Pollution and Spatial Distribution of Temperature. Unpublished M.Sc. thesis, University of Alberta, 70 p.

Fairbairn, W. A., 1968: Climatic Zonation in the British Isles. Forestry, p. 117-130.

Geiger, R., 1957: The Climate Near the Ground. Harvard University Press, Cambridge, Mass., 489 p.

Government of Alberta and the University of Alberta, 1969: Atlas of Alberta. University of Alberta Press and University of Toronto Press, 158 p.

Hayter, R., 1970: Frost Hazard in North-east Alberta. Unpublished M.A. thesis, University of Alberta, 250 p.

Holderidge, L. R., 1959: Simple Method for Determining Potential Evapotranspiration from Temperature Data. Science, September, p. 572.

Holderidge, L. R., 1962: The Determination of Atmospheric Water Movements. Ecology, Vol. 43, p. 1-9.

Kautilya, 1915: Arthasastra, translated by R. Shamasastry. Government Oriental Library Series, Bibliotheca Sanskrita, No. 37, Part 2.

King, L. J., 1969: Statistical Analysis in Geography. Prentice-Hall Inc., Englewood Cliffs, N. J., 288 p.

Kurtyka, J. C., 1953: Precipitation Measurements Study. State Water Survey Division, Urbana, Illinois, 178 p.

Laycock, A. H., 1967: Water Deficiency and Surplus Patterns in the Prairie Provinces. Prairie Provinces Water Board, Prairie Farm Rehabilitation Administration, Regina, Sask., 91 p.

Longley, R. W. and M. Louis-Byne, 1967: Frost Hollows in West Central Alberta. Department of Transport, Meteorology Branch, Tech. Cir. Series Cir. 4532, Tech. 639, 15 p.

Longley, R. W., 1970: Climatic Classification for Alberta Forestry. Proceedings of the Third Forest Microclimate Symposium, p. 147-153.

MacIver, D. C., 1970: A Technique of Thermo Dew-Point Recording in Northern Alberta. Proceedings of the Third Forest Microclimate Symposium, p. 188.

MacPhail, N. G., 1966: A Mobile Technique for Measuring and Recording Air Temperature and Humidity. Department of Transport, Meteorology Branch, Tech. Cir. Series Cir. 4475, Tech. 624, 18 p.

Mather, J. R., 1954: The Measurement of Potential Evapotranspiration. The Johns Hopkins University Laboratory of Climatology, Publications in Climatology, Vol. VII, No. 1, 225 p.

Meteorological Branch, 1954-1969: Monthly Record. Department of Transport, Toronto.

Meteorological Branch, 1968: Climatic Normals. Department of Transport, Toronto.

Newnham, R. M., 1968: A Classification of Climate by Principal Component Analysis and Its Relationship to Tree Species Distribution. Forest Science, 14, No. 3, p. 254-264.

Petterssen, S., 1958: Introduction to Meteorology. McGraw-Hill Book Company, Inc., 327 p.

Prairie Provinces Water Board, 1957: Soil Moisture Budget--Daily Tabulation 1921-1956. Station Beaverlodge, Alberta. Meteorological Section, Division of Field Husbandry, Soils and Agricultural Engineering, Central Experimental Farm, Ottawa.

Reifsmyder, W. E., _et_. _al_., 1970: Solar Climate Calculator. _Proceedings of the Third Forest Microclimate Symposium_, p. 181-187.

Rheumer, G. A., 1953: Climate and Climatic Regions of Western Canada. Ph.D. thesis, University of Illinois, 185 p.

Semple, R. K., _et_. _al_., n.d.: _The Determination of the Optimal Number of Groupings in Classification Problems_. Department of Geography, Ohio State University, No. 10, 63 p.

Thompson, P. T., 1966: A Test of the Holderidge Model in Midlatitude Mountains. _Professional Geographer_, Vol. XVIII, No. 5, p. 286-292.

Thornthwaite, C. W. and J. R. Mather, 1955: _The Water Balance_. The Johns Hopkins University Laboratory of Climatology, Publications in Climatology, Vol. VIII, No. 1, 104 p.

Tosi, J. A., 1964: Climatic Control of Terrestrial Ecosystem: A Report on the Holderidge Model. _Economic Geography_, Vol. 40, p. 173-181.

World Meteorological Organization, 1966: Measurement and Estimation of Evaporation and Evapotranspiration. Technical Note No. 83, 121 p.

Appendix A

The following is a simple example of the general method of factor analysis as outlined by Dr. K. D. Hage. General agreement of this example and the computer program within the thesis is found. Only in the calculation of the final factor scores from the eigenvectors is there any real discrepancy. Instead of direct principal factor calculation from the eigenvectors, the computer program calculates the factor matrix which is then employed as input for the factor scores.

Given two variables, x_1 and x_2 and standard deviations $\sigma_1 = 2.0$ and $\sigma_2 = 1.0$, the correlation between x_1 and x_2 is $r_{12} = 0.5$. Assumed are real roots such that the value r_{12} equals r_{21}. Therefore substitution into the matrix:

$$\begin{vmatrix} \sigma_1^2 - \lambda & r_{12}\sigma_1\sigma_2 \\ r_{12}\sigma_1\sigma_2 & \sigma_2^2 - \lambda \end{vmatrix} = 0 \qquad (1)$$

yields two characteristic roots λ_1 and λ_2

$$\lambda_1 = 4.3 \qquad \lambda_2 = 0.7$$

Substituting the value of λ_1 for λ in equation (1) multiplied by the column vector $\begin{matrix} a_{11} \\ a_{12} \end{matrix}$ and applying the criteria of maximizing the variance by setting the two matrices = 0 yields two equations:

$$(\sigma_1^2 - \lambda_1)\, a_{11} + r_{12}\sigma_1\sigma_2\, a_{12} = 0$$

$$r_{12}\sigma_1\sigma_2\, a_{11} + (\sigma_2^2 - \lambda_1)\, a_{12} = 0$$

Using only the first equation and imposing the criterion that the sum of squares = 1 ($a_{11}^2 + a_{12}^2 = 1$) the resulting of the simultaneous equation for $\lambda_1 = 4.3$ is:

$$a_{11} = \pm .96$$

$$a_{12} = \pm .29$$

If $a_{11} > 0$ then so also must $a_{12} > 0$ such that the principal factor 1 is

$$\xi_1 = .96x_1 + .29x_2$$

If $\lambda = 0.7 = \lambda_2$

the second principal factor is

$$\xi_2 = -.29x_1 + .96x_2$$

It is the plotting of these factors which discriminates between stations, providing a method of statistical grouping.

Appendix B

ALPINE MEADOW		Varied species
MUSKEG	MB	Sphagnum moss - Black Spruce, treed muskeg
FOREST LAND	JW	Jackpine - White Spruce
	LWE	Lodgepole Pine - White Spruce - Engelmann Spruce, altitudinally zoned
	LW	Lodgepole Pine - White Spruce
	LA	Lodgepole Pine - Aspen Poplar
	LS	Lodgepole Pine - Spruce
	Aes	Aspen ecotone to Spruce
	A	Aspen Poplar
	Ap<50%	Aspen Poplar with grass less than 50% cultivated
	Ap>50%	Aspen Poplar with grass more than 50% cultivated
	A >50%	Aspen Poplar more than 50% cultivated
	A <50%	Aspen Poplar less than 50% cultivated
	Aes<50%	Aspen ecotone to Spruce less than 50% cultivated

SPECIAL COLLECTIONS

UNIVERSITY OF ALBERTA LIBRARY

REQUEST FOR DUPLICATION

I wish a photocopy of the thesis by

Donald C. MacIver (author)

entitled Macroclimatic Zonation in Northern Alberta.

The copy is for the sole purpose of private scholarly or scientific study and research. I will not reproduce, sell or distribute the copy I request, and I will not copy any substantial part of it in my own work without permission of the copyright owner. I understand that the Library performs the service of copying at my request, and I assume all copyright responsibility for the item requested.

F. 236 September 1975


120°
118°
116°
114°
112
110°
56°
54°
PEACE RIVER
Fairview
Rycroft
Falher
Salt Prairie
Doucette Lookout
Wabasca
PELICAN MOUNTAINS
Pelican Mountain
Marten Mountain
LESSER SLAVE L.
Kinuso
Wagner
SLAVE RIVER
Slave Lake
High Prairie
Grande Prairie
Beaverlodge
WAPITI RIVER
Puskwaskau
House Mountain
Sweathouse Lookout
Economy Lookout
Bald Mountain
SWAN HILLS
Deer Mountain
Swan Dive
Goose Mountain
Snuff Mountain
Kakwa Lookout
Pimple Lookout
SMOKY RIVER
Simonette Lookout
ATHABASCA RIVER
Whitecourt
Whitecourt Lookout
Campsie
Athabasca 2
Athabasca
Meanook
Rochester
Newbrook
Sion
Conklin Lookout
Round Hill
Heart Lake Lookout
Lac la Biche
BEAVER RIVER
Iron River
Cold Lake
Elk Point
NORTH SASKATCHEWAN RIVER
Fort Saskatchewan
Ranfurly
Vegreville
Vermilion
Calmar
Thorsby
ROCKY MOUNTAINS
Edson
Entrance
Hinton
Yellow Head
0 20 40 60 80 100 Miles

B29958